MONITORING SURVIVAL AND MOVEMENT PATTERNS OF SEA OTTERS (*ENHYDRA LUTRIS KENYONI*) IN KACHEMAK BAY, ALASKA AUGUST 2007-APRIL 2010

BY

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ABSTRACT
Sea otters (*Enhydra lutris kenyoni)* strand and die for a variety of reasons, including disease, starvation, predation, and trauma. Beginning in 2006, there was an unusually high number of subadult male sea otters dying from *Streptococcal endocarditis*, encephalitis and/or septicemia, referred to as *Strep*. syndrome in Kachemak Bay, Alaska. To better understand the progression of the *Strep.* syndrome in free-ranging sea otters, the U.S. Fish and Wildlife Service implanted VHF radios into 44 sea otters in Kachemak Bay to monitor health, survival, and movements, and to assess causes of mortality. During 31 July 2007 – 03 May 2010, we monitored 12 female (4 subadults, 8 adults) and 32 male (2 pups, 16 subadults, 14 adults) sea otters by aircraft and remote data logger (2008-2010 only). The average period between locations of each study animal was 12 days. By January 2010, the status of the study animals was: 30 alive, 6 dead, and 8 missing. After January 2010, the rate of detection progressively decreased due to the expiration of the battery life of the radio transmitters. We continued to locate study animals to monitor for mortality, and at the close of the monitoring, on 03 May 2010, the status was: 9 alive, 6 dead, and 29 missing. Study animals may be missing (undetected) for a variety of reasons, including radio failure, movement outside the study area, and undetected mortality. Causes of mortality were disease (2 adult females), trauma due to boat strike (1 adult male), and take during subsistence hunting (3 adult males). Both females and the male which died of trauma had forensic level necropsies performed; the female otters showed evidence of *Strep.* syndrome and the adult male did not. Male and female otters used spatially distinct regions of the Bay, and both sexes appear to have seasonal use patterns. During the monitoring period, all females had at least 1 pup; on average, a pup was born to each female every 1.2 years, indicating ample food resources. At the close of the study, all subadult males were alive, with one (6%) missing, whereas 58% of the female otters were either dead or missing. Carcass collection methods are biased by the habitat used by particular sex and age classes of otters and the areas available to be searched by stranding volunteers. Carcass recovery efforts indicated that subadult male otters were more vulnerable to Strep. syndrome than other sex and age classes, however, this study indicates that reproductive-age female otters may be more vulnerable. The survival of females appears particularly low (50%), however, our sample size was small (n=12). Of the known causes of mortality in our study, 67% are directly human related (boat strike and harvest) in Kachemak Bay. While the overall mortality rate for the Kachemak Bay study area is likely not significant on a broad population level, this study has been informative and elucidates the ease at which unreported and undocumented mortality can occur in this, or likely any other, region within the population range.

INTRODUCTION

Sea otters (*Enhydra lutris kenyoni)* strand and die for a variety of reasons, including disease, starvation, and trauma in Alaska. In the Kachemak Bay area, there has been an unusually high number of subadult male sea otters dying from *Streptococcal endocarditis*, encephalitis and/or septicemia (hereafter referred to as the *Strep*. syndrome) (Gill *et al.* in prep). Because *Strep*. syndrome was the most frequent cause of death for recovered sea otter carcasses in Kachemak Bay, the U.S. Fish and Wildlife Service (FWS) recommended the event be investigated in collaboration with the Unusual Mortality Event (UME) team which is provisioned under the Marine Mammal Protection Act. With a dedicated team of researchers, the FWS implemented several studies to both identify causes of the syndrome and to understand the potential impact to the population. Early findings indicate that most of the isolates in the Strep. syndrome of sea otters in Alaska are *Streptoccous infantarius ssp. coli* (Burek *et al*. in prep). The cause of this unusually high occurrence of the disease is unknown. However, there is evidence of a morbillivirus and Bartonella in this population, which could lead to immunosuppression and/or damage to endothelial cells (UME team, unpublished data). To understand the progression of the *Strep.* syndrome, and to relate findings from the necropsy work to live free-ranging sea otters, the FWS and the Alaska SeaLife Center implanted a VHF radio into each of 44 sea otters in Kachemak Bay during late summer 2007. The study objectives were to evaluate individual health profiles for the study animals, to collect data on survival and causes of mortality, and to understand habitat use through monitoring movements. We report the results of the radio monitoring, (including reproduction, behavior, habitat use), and causes of death of these radio-implanted sea otters.

METHODS

Study Area: Kachemak Bay is located in Southcentral Alaska (59.6º N and 151.5º W) and is designated as a State Critical Habitat Area. It is also the location of the Kachemak Bay National Estuarine Research Reserve. The study area is approximately 916 km^2 of estuarine and fjord habitats which are influenced by glacial input in the summer and by adjacent waters of lower Cook Inlet and the Gulf of Alaska (Fig. 1). The bathymetry is characterized by average water depths of 41-meters, soft-sediment substrates of unconsolidated glacial till, and silt and deep trenches and holes extending to approximately 170-meters deep. A 6-kilometer long spit, a relict glacial moraine, extends south from the city of Homer to the center of the Bay restricts water circulation. The south side of the Bay is generally deep with rocky substrate, and the north side is shallow with soft sediment habitats. Meltwater from fifteen glaciers flows into Kachemak Bay from the Harding and adjacent ice fields. Sediments derived from these glaciers help build and sustain the predominantly sand and gravel beaches in the estuary. Nutrient rich water enters the Bay from the Gulf of Alaska, and large tidal ranges (mean 5.5meters) contribute to the circulation pattern.

Capture and Clinical Data: Capture, handling, and release procedures followed well established protocols (Ralls *et al.* 1989, Monson *et al.* 2001) and were approved by the University of Alaska, Anchorage Animal Care and Welfare Committee. We captured sea otters passively with unweighted tangle nets placed selectively in high density sea otter habitat. Once captured, the sea otters were transferred to a support vessel standing by in proximity to the capture site. Sea otters were anesthetized with a combination of fentanyl citrate and diazepam or midazolam anesthesia, and reversed with naltrexone. Weight (kg) and length (cm) were recorded, and a premolar tooth was collected for aging (Bodkin *et al.* 1997). Otters were tagged with a VHF radio in the interperitoneal cavity, and color-number coded plastic tags (Temple Tags, Temple, TX) were inserted with a single punch in the interdigital space on the hind flipper for visual identification. To aid in the recovery of dead study animals, all radios had a temperature mortality sensor which increased the pulse rate post mortem.

Sea otter ages were classified by tooth cementum of the first premolar tooth (Matson's Lab). Age classes for study animals were defined as follows: 0-1 were dependant pups; >1 and <5 were subadult unless accompanied by a dependant pup; ≥ 5 were classified as an adult.

Monitoring: We monitored for radio instrumented animals following surgical implantation to ensure full recovery from surgery and sampling procedures and continued monitoring through 03 May 2010. Monitoring of study animals by fixed-winged aircraft occurred three times per week, on average. For each location we recorded date, time, location (GPS latitude/longitude), group size, location quality, behavior (forging, resting, interacting, swimming, unknown), and pup status. We classified the relative accuracy of each location as high quality (≤ 0.5 km) or low quality (>0.5 km), and visually confirmed the study animal's location when feasible. Behavior was determined by visual observation of the study animal or by interpretation of the radio signal pattern (a resting animal has no break in signal transmission; a foraging animal has distinct breaks in transmission with each foraging dive; grooming and swimming animals have an irregular patterning to the signal transmission). In order to passively monitor sea otters, we installed a remote data logger in our study area in Mud Bay during November 2008, this area is used seasonally by large concentrations of sea otters. A radio transmitter of known frequency served as a reference signal, and the data logger scanned continuously. See Appendix A for more details on monitoring methods.

RESULTS

Capture and Clinical Data: We had a capture rate of 2.09 otters per day over 21 capture days. We captured and sampled 44 sea otters in Kachemak Bay: 12 female (4 subadults, 8 adults) and 32 males (2 pups, 16 subadults, 14 adults). Tooth age was used to classify age in all cases but two (LCI018 and LCI027) where the first premolar tooth had not been collected during surgery. In these cases, the estimated age at capture was used (Table 1). At the beginning of the study, age classifications were based on tooth annuli and behavior at the time of capture. Age classifications were modified as study animals were observed as independent (in the case of pups) or reproductively mature (subadult females). All sea otters were sampled, implanted with a VHF radio, and released in proximity to the capture location. There were no mortalities resulting from capture, sampling, or surgery. At the time of capture, all study animals appeared in good condition on gross observation, and subcutaneous fat was evident at the time of surgery. Analyses of clinical samples collected during the sampling procedure are reported in Goertz *et al.* 2007.

Monitoring: During 31 July 2007 – 03 May 2010, we actively monitored the study animals by aircraft (n=3,277 total relocations) and remote data logger (2008-2010 only). For male and female study animals, the average number of relocations was 79 (85% high quality) and 62 (83% high quality), respectively, by aircraft (See Appendix B for maps of individual study animals). The radio transmitter signal was not found to be particularly strong for these study animals, and the aircraft was most often within 1 km of a target transmitter before the signal was heard. Therefore, even the low quality locations were still within 1 km of the actual location of the study animal. The average interval between relocations was 12 days. When conditions allowed, we located study animals visually from the aircraft. Missing study animals were searched for outside of the study area in Cook Inlet (n=49 flights). In total, 9,421-kilometers of track lines outside of the study area were searched while 125,525 kilometers (n=431 flights) were searched inside of the study area (Fig. 1). External tag loss increased throughout the study, with most tags visible in year one to only 9 of 38 otters that retained at least one tag by May 2010. Most study animals were found to be alone or in small groups of sea otters (<20) when relocated, and the maximum group size was 500 (Fig. 2). The behavior at the time of relocation varied: 47% resting or hauled-out, 20% foraging, 17% swimming, 1% other behavior (such as interacting with other sea otters), and 15% unknown activity.

Table 1. Capture and tagging information from 44 sea otters which were instrumented with VHF radio transmitters in the intreperitoneal cavity and systematically monitored during 31 July 2007 – 03 May 2010 in Kachemak Bay, Alaska.

Otter Number	Capture Date	Left Tags	Right Tags	VHF Radio Frequency	Sex	Age (Yrs)	Weight (kg)
LCI001	07/24/2007	CH-45-251	AQ-45-556	165.392	M	8	41.0
LCI002	07/24/2007	LB-45-264	AQ-45-567	165.882	F	6	24.9
LCI003	07/24/2007	OR-45-301	AQ-45-558	164.530	F	4	24.9
LCI004	07/25/2007	RE-45-485	AQ-45-560	164.430	F	14	27.2
LCI005	07/25/2007	WH-45-519	AQ-45-563	165.603	M	0	16.8
LCI006	07/25/2007	YE-45-271	AQ-45-551	164.780	M	6	41.3
LCI007	07/25/2007	AQ-45-568	AQ-45-554	165.180	F	11	29.0
LCI008	07/26/2007	PI-45-16	AQ-45-553	164.942	M	8	38.6
LCI009	07/29/2007	PU-45-6	AQ-45-566	165.304	F	5	26.8
LCI010	07/29/2007	CH-45-265	CH-45-257	165.055	M	3	35.8
LCI011	07/30/2007	LB-45-255	CH-45-263	164.668	F	2	24.5
LCI012	07/30/2007	OR-45-307	CH-45-262	165.243	M	6	38.6
LCI013	07/30/2007	RE-45-500	CH-45-264	165.155	F	8	26.4
LCI014	07/30/2007	WH-45-532	CH-45-261	164.641	M	0	17.3
LCI015	07/30/2007	YE-23-273	CH-45-266	164.717	F	2	20.9
LCI016	07/30/2007	AQ-45-562	CH-45-254	165.364	F	10	27.3
LCI017	07/31/2007	PI-45-15	CH-45-258	164.993	F	3	27.3
LCI018	08/02/2007	PU-45-1	CH-45-252	165.278	M	5	34.1
LCI019	08/02/2007	CH-45-260	LB-45-256	164.405	M	2	30.0
LCI020	08/02/2007	LB-45-252	LB-45-266	164.504	M	2	35.9
LCI021	08/02/2007	OR-45-312	LB-45-253	164.891	M	2	27.7
LCI022	08/02/2007	RE-45-497	LB-45-251	164.453	M	3	36.4
LCI023	08/02/2007	WH-45-531	LB-45-259	165.015	M	4	38.6
LCI024	08/04/2007	YE-45-279	LB-23-267	165.079	M	2	33.2
LCI025	08/04/2007	AQ-45-564	LB-45-258	165.328	M	2	31.2
LCI026	08/04/2007	PI-34-12	LB-45-263	164.618	M	2	30.0
LCI027	08/04/2007	PU-45-5	LB-45-260	164.692	M	5	36.4
LCI028	08/04/2007	CH-45-256	OR-45-302	164.742	M	8	35.0
LCI029	08/05/2007	LB-45-257	OR-45-303	164.804	M	7	33.6
LCI030	08/05/2007	OR-45-313	OR-45-304	164.970	M	7	43.2
LCI031	08/05/2007	RE-45-495	OR-45-305	164.842	M	8	35.5
LCI032	08/07/2007	WH-45-524	OR-45-306	164.865	M	7	40.0
LCI033	08/07/2007	YE-45-268	OR-45-308	164.555	M	4	38.2
LCI034	08/07/2007	AQ-23-557	OR-45-309	164.917	M	9	40.5
LCI035	08/07/2007	PI-45-13	OR-45-314	165.416	M	5	35.5
LCI036	08/07/2007	PU-45-4	OR-45-310	165.215	M	7	31.8
LCI037	08/07/2007	CH-45-253	PI-45-1	164.592	M	3	35.5
LCI038	08/07/2007	LB-45-261	PI-34-2	164.605	M	2	28.6
LCI039	08/07/2007	OR-45-315	PI-45-9	164.417	M	2	30.0
LCI040	08/09/2007	RE-45-498	PI-45-4	164.516	M	1	23.6
LCI041	08/09/2007	WH-23-530	YE-45-270	164.679	F	4	33.2
LCI042	08/10/2007	YE-45-274	YE-45-272	164.655	M	4	34.0
LCI043	08/10/2007	AQ-45-561	YE-45-276	164.541	M	4	37.3
LCI044	08/11/2007	PU-45-8	YE-45-278	165.618	F	10	27.3

From October through April each year, large groups of male otters (50 - 200) congregate in the water and on the ice floes near Mud Bay (Fig. 1). The remote data logger was useful in identifying seasonal habitat use of Mud Bay. From November 2008 – May 2010, 27 male study animals were recorded at the Mud Bay site; on average, an individual was heard on 114 different days (range 2-233 days). Six female otters used the Mud Bay site on an average of 5 different days (range 1-14 days). The mortality signal of another adult female otter was also recorded at this site. She had previously been located dead and floating in the open water at the mouth of Kachemak Bay, but we were unable to recover the carcass. Four days later, the tides and currents brought her body to Mariner Park on the outside of the Homer Spit and the data logger recorded her mortality signal.

By January 2010, the status of the study animals was: 30 alive, 6 dead, and 8 missing. After January 2010, the rate of detection progressively decreased until 66% of the study animals were missing (radio battery expiration was the assumed cause, Fig. 3). We continued to locate study animals to monitor for mortality, and at the close of the monitoring, on 03 May 2010, the status was: 9 alive, 6 dead, and 29 missing. Causes of mortality for our study animals were disease (2 adult females), trauma due to boat strike (1 adult male), and take during subsistence hunting (3 adult males) (Table 2). Forensic level necropsies were conducted on the 2 adult females and 1 adult male (boat strike). Both of these female study animals showed some evidence of *Strep*. syndrome. Female LCI004 had muscle wasting, septicemia, and a recently aborted pregnancy. Female LCI007 had probable septicemia, endocarditis, and was lactating at the time of death. On the last visual observation of LCI007, she had a small pup (approximately 2.5 months); the fate of the pup is unknown but it was likely too small to survive on its own. At the time of necropsy, there was no evidence of the *Strep*. syndrome in male LCI031 which died of severe trauma, likely from a boat strike.

We were unable to recover the three bodies of the sea otters taken in the subsistence hunts. LCI036, a territorial male from Halibut Cove, was taken as part of a subsistence hunt and the carcass was left in the water at the hunting site. The hunter retained and returned the flipper tags to us; we did not locate a radio signal from this otter despite extensive searching by aircraft. The second hunted animal (LCI006) was tracked to the hunter’s house. When asked, he brought the carcass to Homer for tagging and provided the heart for examination, but did not wish to provide the carcass for necropsy. The heart showed a thickening of the heart valves and may have been in a preliminary stage of endocardiosis, but we were unable to determine if there was other evidence of *Strep*. syndrome for this animal without a necropsy (P. Tuomi pers. com). The transmitter of LCI001 was recovered on 27 April 2009 on the beach at Ninilchik, but the carcass had already been scavenged. When talking with residents of the area, they had found 3 carcasses dumped on the beach (2 adult, 1 subadult or large pup) around 10 April 2009 that were skinned with the heads still attached. One of these animals was LCI001. He was a territorial male that spent most of his time in Tutka Bay.

Of the missing animals, we lost contact with three animals (2 females, 1 male) in 2008 and five animals (3 females, 2 males) in 2009. On 1 July 2009, a kayaker spotted an otter with a pup that had flipper tags matching the color combination of LCI015, so it is possible that her transmitter stopped working. Unfortunately, we were unable to verify the sighting and no further reports of this otter were obtained.

Table 2. The monitoring results of 44 VHF radio-tagged sea otters for survival and causes of mortality during 31 July 2007 - 01 January 2010 in the Kachemak Bay, Alaska.

Otter ID	Age	Sex	No. of Resight Locations	Date of Last Resight	Status	Necropsy Preformed	Necropsy Result
LCI001	8	M	60	04/27/2009	Dead	No	Subsistence Hunt
LCI004	14	F	21	04/17/2008	Dead	Yes	Disease
LCI006	6	M	33	11/15/2008	Dead	No	Subsistence Hunt
LCI007	11	F	50	01/26/2009	Dead	Yes	Disease
LCI031	8	M	8	03/06/2008	Dead	Yes	Trauma
LCI036	7	M	21	03/16/2008	Dead	No	Subsistence Hunt
LCI002	6	F	41	01/06/2009	Missing		
LCI009	5	F	69	09/26/2009	Missing		
LCI015	2	F	40	12/16/2008	Missing		
LCI016	10	F	29	09/23/2008	Missing		
LCI017	3	F	77	09/13/2009	Missing		
LCI029	7	M	67	05/24/2009	Missing		
LCI034	9	M	29	05/13/2008	Missing		
LCI039	2	M	74	07/01/2009	Missing		

During the monitoring period, cumulative plots of relocations by sex show the majority of coastal and open water areas in Kachemak Bay were used by our study animals, with the exception of the deepest waters in the center of the Bay (Fig. 4 and 5). There was overlap in male and female areas throughout the study area but pup rearing by adult females was more distinct and occurred in the open water habitat at the mouth of the Bay, within the more protected coastal areas on the south side of the Bay, and was rarely seen at the head of the Bay (Fig.6). Male otters were most commonly found around the Spit (Fig. 4), and rarely found along the south shore of the Bay, with the exception of established territories for males LCI001, LCI027, LCI028, LCI030, LCI033, and LCI036 during a portion of the monitoring period (Fig. 7). The average water depth associated with locations for male and female otters was 18-meters and 19-meters, respectively, with more haul-out behavior observed in the winter months. The average water depth of the overall study area was 41-meters (range 0 – 169m).

With a mean location interval of 12 days, we were able to detect the presence of pups born to females more easily than expected given that we were monitoring by aircraft. All females produced at least 1 pup during the course of the monitoring period, and those animals that were tracked for all three years produced 2 or 3 pups. On average, females in our study reproduced every 1.2 years. We estimate the age of first reproduction for three females that were captured as subadults to be between 3 and 4 years of age.

DISCUSSION

Sea otters in Kachemak Bay use the open water habitat for foraging, resting, and pup rearing. The tendency to reside in the open water affected our rate of capture. The rate of capture was about half of what we obtained in the Kodiak archipelago during 2004-2005 which averaged 4.2 otters per day (Doroff pers. obs.). Though the Kodiak archipelago has similar soft sediment foraging habitats and strong tidal currents, the otters were typically closer to shore than observed in Kachemak Bay, and unweighted tangle nets set perpendicular to travel corridors were an effective capture method. In Kachemak Bay, there was only one site where shore-based nets were effective, and the rest of the effort was in the open water habitat.

The tendency for otters to use the open water habitat also affected our ability to relocate study animals. Otters were found as far away as 16-kilometers from shore, and because of the short transmitter range and the amount of open water to search, otters at this distance were very difficult to locate. Our goal was to locate each study animal every 7 days, and we averaged 12 days between observations. Wave height and otter behavior (movements) often impeded our ability to obtain a steady signal from the study animals. Swimming animals can be very low in the water and, in some cases, groups of animals will swim en mass on their bellies when traveling. Both behaviors reduce the probability of detection. External tag loss may have contributed to the monitoring efficiency, but to a much lesser degree. Tags were regularly detected at the beginning of the study, but steadily decreased over time during the monitoring. At the time of capture, the lead veterinarian noted that several of the study animals had bite wounds on the hind flippers which indicated high intraspecific interaction among otters in this area. Factors affecting tag retention include animal behavior, tag placement on the webbing, and whether the tag was a single hole or double hole punch. In this study, we elected to do a single rather than double flipper punch in applying the tags even though it is likely that a double hole punch is more secure (Bodkin pers. com). Because our primary means of monitoring was by aircraft, we were not able to detect behaviors that would indicate intraspecific interactions which would result in tag loss but we were able to discern multiple behaviors such as resting, foraging, swimming, and grooming. Foraging activity occurred throughout the Bay, with the exception of the deepest waters (Fig.8). In general, our study animals used most of the Bay but use patterns varied somewhat by season and reproductive status (pup rearing and territoriality). Females used open water habitat at the mouth of the Bay and coastal habitat along the south side of the Bay more extensively for pup rearing than the protected waters at the head of the Bay.

The primary purpose of this study was to identify the health and condition of free-ranging sea otters in this area and to be able to monitor the progression of the *Strep.* syndrome. Our study animals appeared to be healthy at capture. Weights and body lengths were similar to sea otters captured in the Kodiak archipelago (2004-2005), an area not limited by food resources (Doroff pers. obs.). Age at first reproduction may be related to food availability and overall body condition. At capture, all study animals had subcutaneous fat at the time of surgery indicating a relatively good body condition. Female sea otters can begin producing pups as young as 2.5 years of age (Monson *et al.* 2000; Monson and DeGange 1995; von Biela 2007). In our study, all female study animals produced at least one pup during the course of the monitoring period, and some produced as many as three pups. The youngest age at first reproduction was approximately three years, and females produced pups every year, on average. Though the data collection is not frequent enough to identify when a pup may be lost, or to identify dependency periods, it is clear that pups are being born at a high rate and at a young age in this population, indicating that the otters in Kachemak Bay are not food stressed.

The majority of sea otters recovered dead through the Marine Mammal Stranding Network and the FWS from Kachemak Bay were subadult male animals (Gill *et al.* in prep). Of the 44 tagged sea otters in this study, 16 were subadult males at the time of capture, and at the close of the study only one was missing (6%). Conversely, 58% of the 12 female otters captured in this study were dead or missing at the close of the study. Using the collection of carcasses to indicate the most sensitive segment of the population to this disease may be biased by the habitat used by particular sex and age classes of otters, as well as the geographic locations of where stranding volunteers are able to search and respond to dead or moribund animals. Most of the sea otter carcasses and moribund animals have been recovered along the Homer Spit and near Mud Bay; our tracking data indicate that these areas are primarily used by adult and subadult male otters. The two study animals that died of disease were older (>10yrs) females who reared pups during the study (the upper limit for female otters is about 20yrs). Adult females may be a much more sensitive segment of the population to monitor for disease, but the frequency of carcass collection is much reduced for this sex and age class because of the habitat they use in Kachemak Bay.

During the 2.75 year monitoring period, the known causes of mortality were trauma, *Strep*. syndrome, and harvest. If we assume the sample of otters captured in Kachemak Bay is representative of all sea otters living in the study area, we would expect that approximately 5% of the population may die due to disease, 7% die as part of the Native harvest, and 2% due to boat strikes. If we assess the overall annual loss rate for the population, it would result in a range from 5% yr^{-1} (all missing animals assumed to be alive) to 12% yr^{-1} (all missing animals assumed dead). Documented annual adult mortality rates for areas in the sea otter range that are not food limited are relatively low, and range 4%-14% for adult animals with slightly higher rates for males than females (Monson and DeGange 1995). Study animals may be missing (undetected) for a variety of reasons, including radio failure, movement outside the study area, and undetected mortality. The battery life at implant was targeted for 2 years and we continued data collection for up to 2.75 years. In that time, we had one possible radio failure, though we were unable to confirm it. Because of the lack of flipper tag retention, an otter's disappearance due to radio failure would be very difficult to detect. Movement outside the study area is also possible; however, we detected no long range movements (i.e., regular long absences and returns of study animals from, and returning to, the intensively monitored area). Undetected mortality was certainly possible, as demonstrated by the subsistence hunter who released the carcass back into the water and the radio was never heard from again during the study. The only reason we knew this animal had been taken was because the hunter brought in the external flipper tags to the FWS and provided us with the information. The two other study animals which were hunted would have likely gone unreported or undetected. One was only known to be part of a subsistence hunt because the radio was tracked to the hunter's home (the hunter did not wish to participate in the study and elected to keep the carcass, but provided us with the flipper tags, radio transmitter, and the heart to examine for lesions). The second unreported study animal was found outside of the study area on an ancillary tracking event; the body was dumped on the beach with two other dead otters (all had their pelts removed). There were no reports in the FWS Marking, Tagging, and Reporting database that fit the description of these takes as part of the legal harvest. The recoveries of two dead adult females in this study were fortuitous; in both cases, we found the study animals before the extreme tides took them out to sea, thus rendering them unrecoverable.

It is likely that some of our missing female study animals are dead; radio failure would not likely have been biased toward female study animals and 5 of 8 missing animals were female. In general, females rearing pups have smaller home ranges than subadult and adult males and are therefore less likely to make long-distance movements (Kage 2004; see Fig.6) which provides an indication that our missing female study animals likely did not leave the study area. Our sample size of females was small in this study (n=12), however, the survival of this group appears particularly low (50%), with five animals missing/assumed dead and one assumed radio failure for female otters. Of the known causes of mortality in our study, 67% are directly human related (boat strike and harvest) in Kachemak Bay. Similarly, in the Kodiak archipelago, human related causes were the highest source of mortality (Monson and DeGange 1995). While our overall reported or known mortality is not likely significant on a population level, it is informative and elucidates the ease at which unreported and undocumented mortality can occur in this, or likely any other, region within the population.

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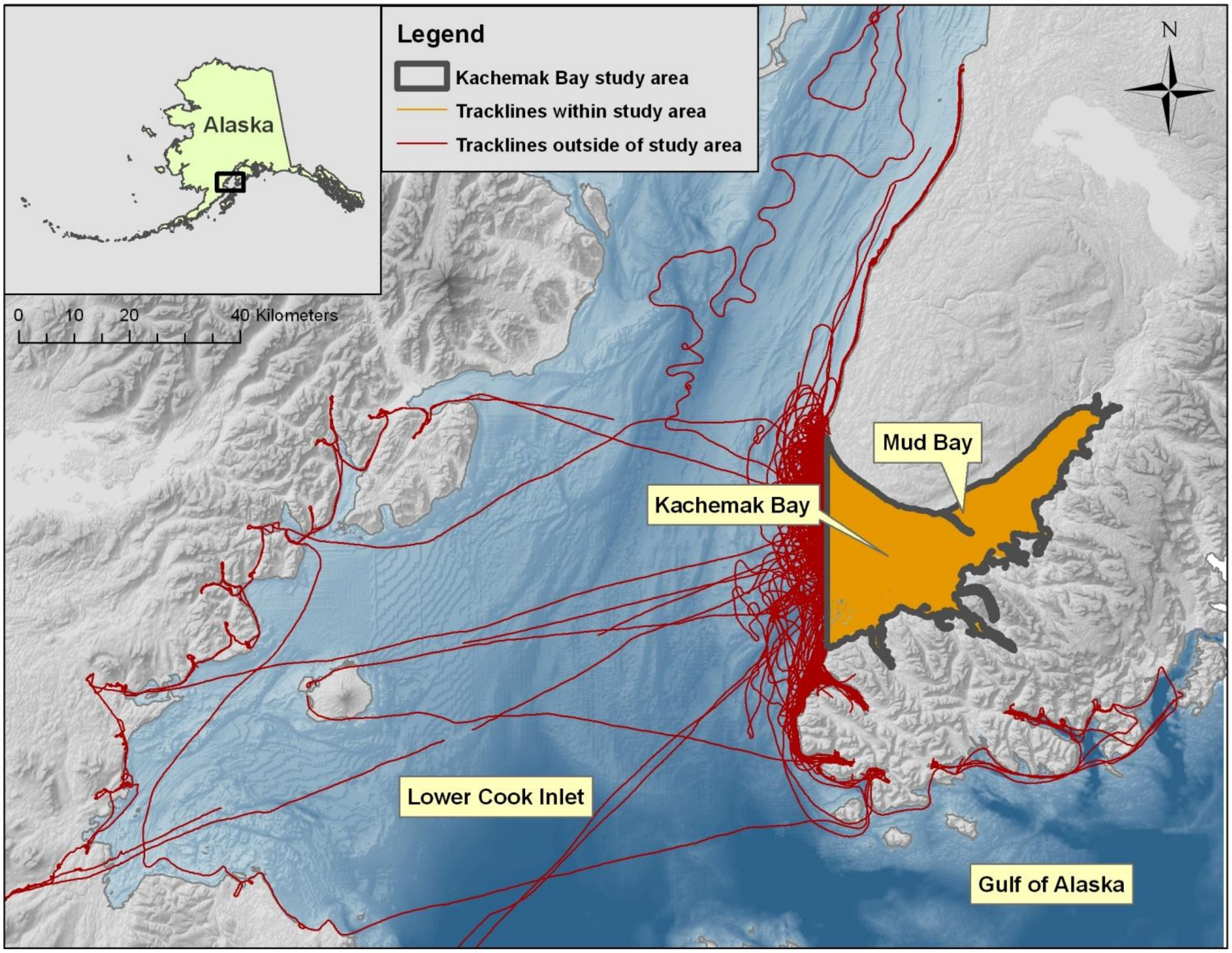


Figure 1. The core study area was located in Kachemak Bay, Alaska, and sea otters with VHF radio transmitters were relocated each week by aircraft. Areas outside of the core study area were searched intermittently for missing animals. The remote data logger was set up to identify seasonal habitat use of Mud Bay.

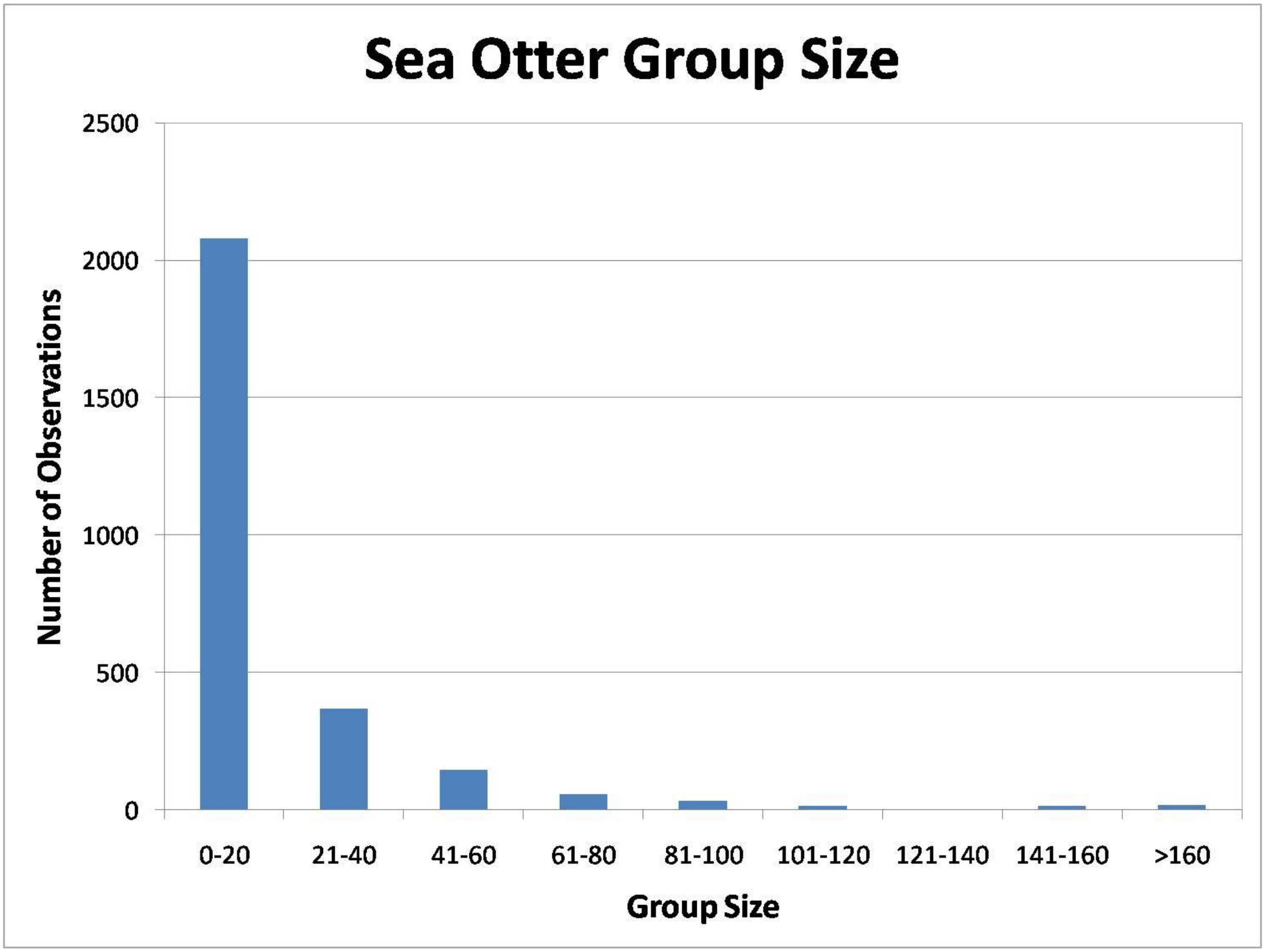


Figure 2. Group sizes at relocation for 44 sea otters with VHF radios (n=2768 high quality relocations). For all sex and age classes combined, the group size most frequently encountered at the time of each relocation was ≤ 20 sea otters.

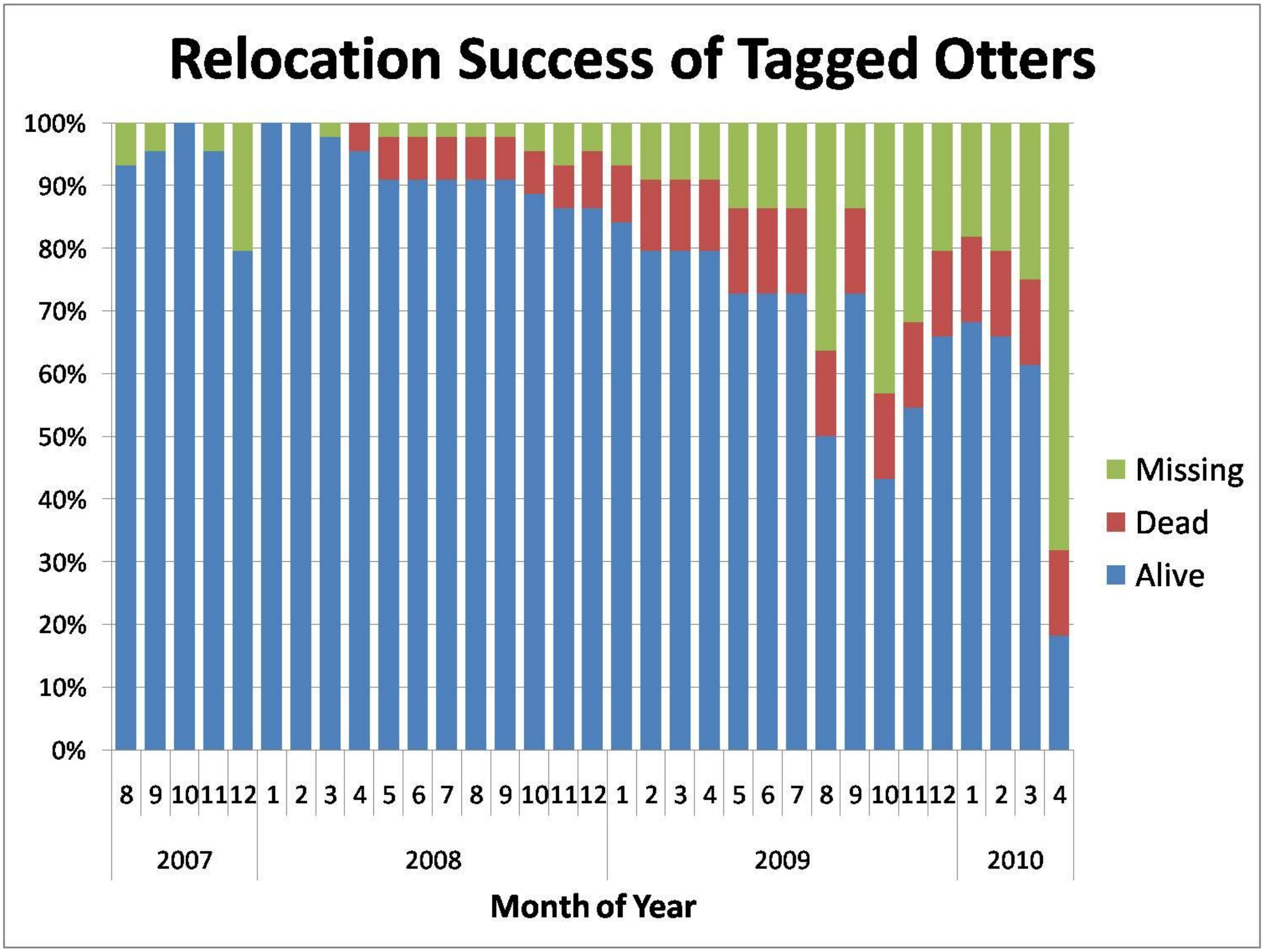


Figure 3. Percentage of sea otters (n=44) in our study which were relocated each month throughout August 2007-April 2010. In 2010, the rate of detection progressively decreased until 66% of the study animals were missing (radio battery expiration was the assumed cause). At the close of the monitoring on 03 May 2010, the status was: 9 alive (20%), 6 dead (14%), and 29 missing (66%).

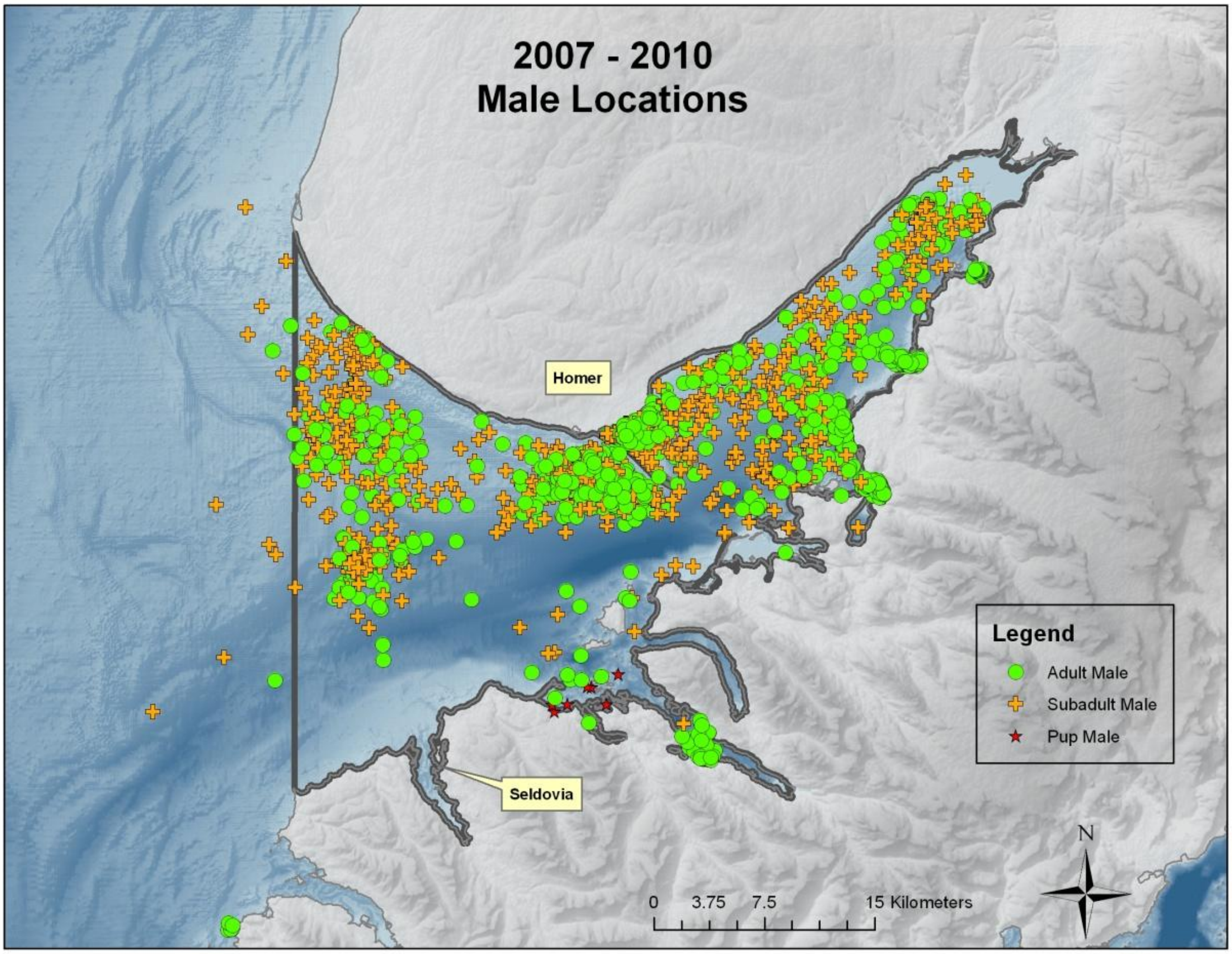


Figure 4. Cumulative plot of high quality relocations (n=2147) for 32 tagged male otters (2 pups, 16 subadults, 14 adults) from August 2007-April 2010.

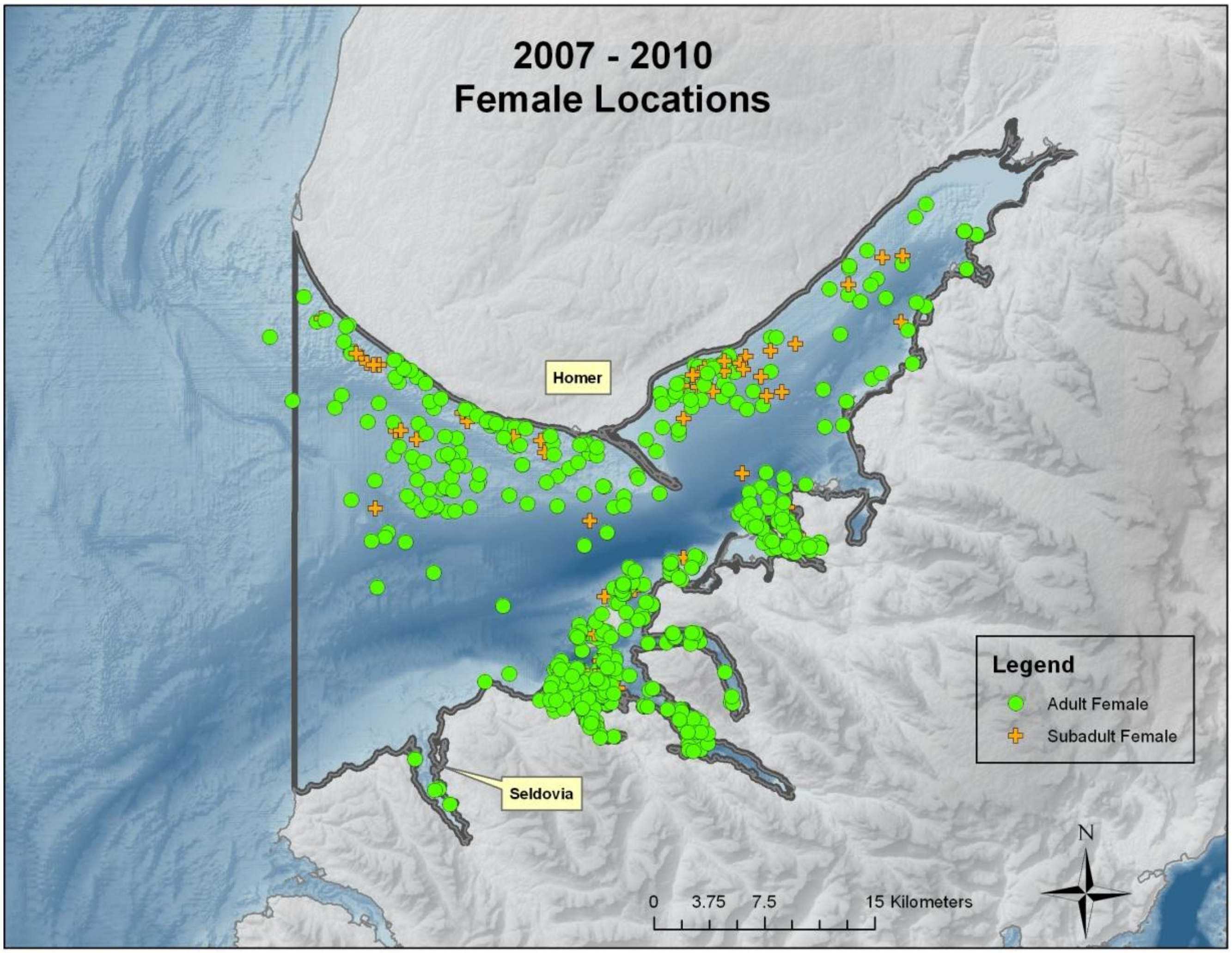


Figure 5. Cumulative plot of high quality relocations (n=621) for 12 female tagged otters (4 subadults, 8 adults) from August 2007-April 2010.

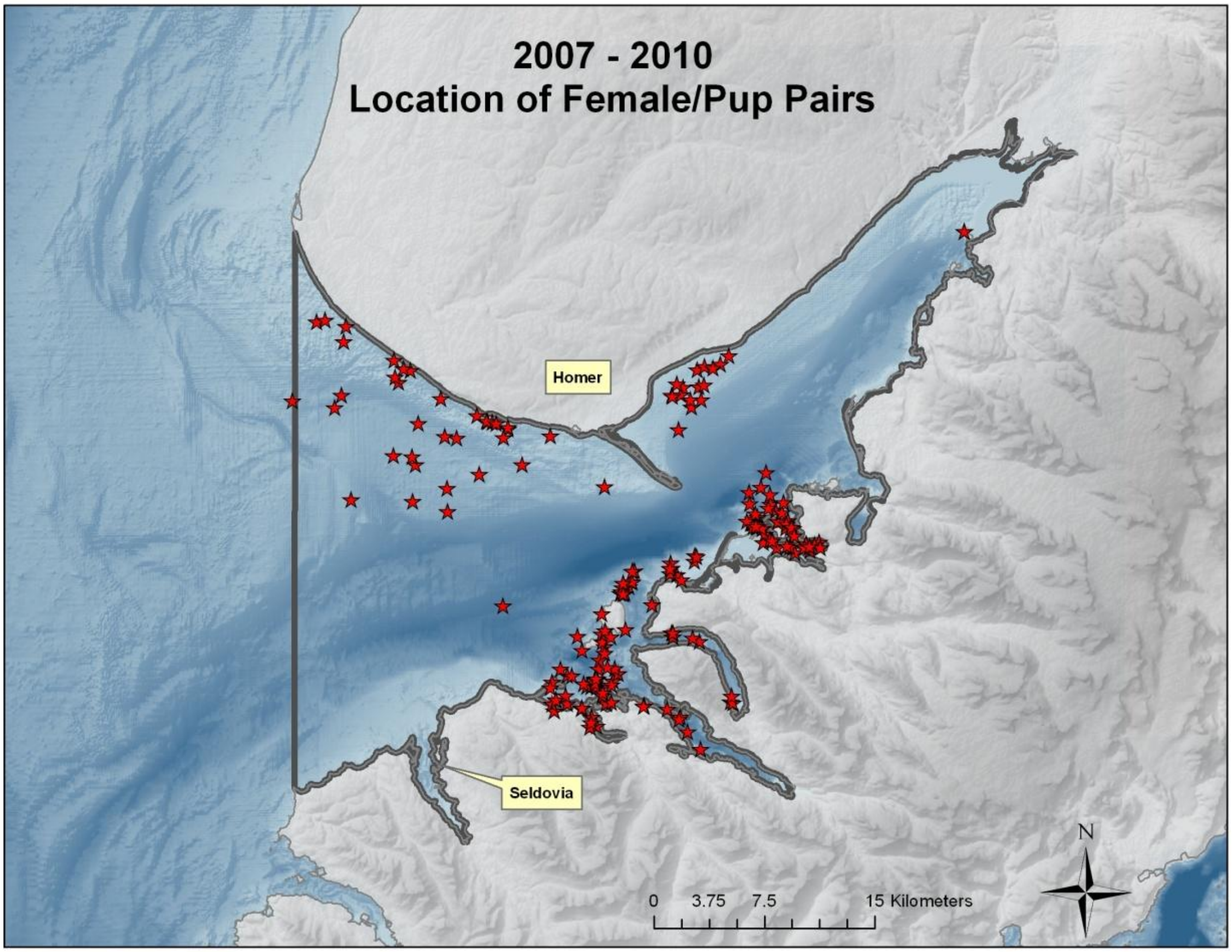


Figure 6. Cumulative plot of high quality relocations (n=196) of tagged adult female sea otters with dependent pups from August 2007-April 2010.

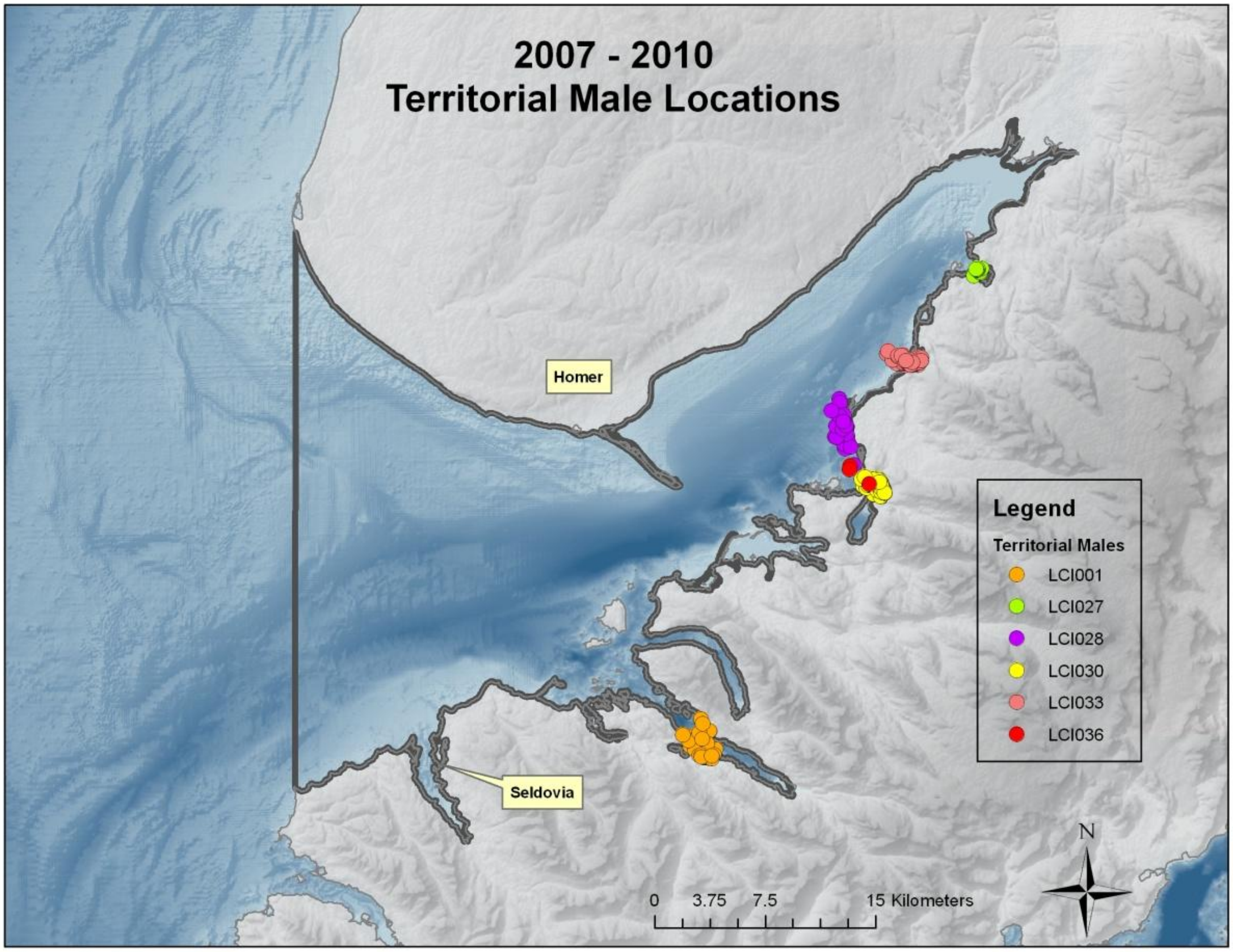


Figure 7. Male otters were rarely found along the south shore of the Bay, with the exception of established territories for males LCI001, LCI027, LCI028, LCI030, LCI033, and LCI036. This figure depicts locations of the tagged males while they were actively territorial (see appendix B for all relocations).

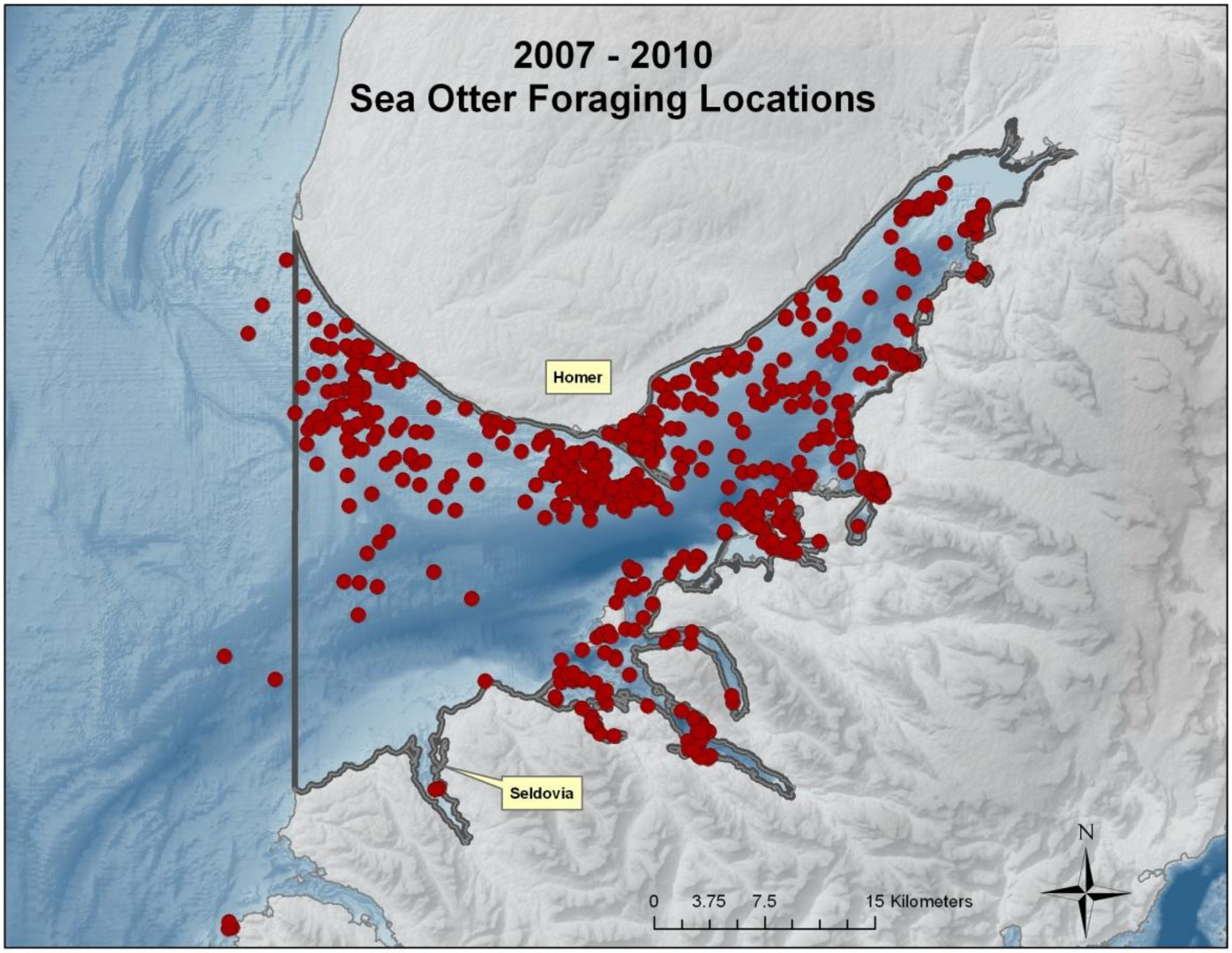


Figure 8. Cumulative plot of high quality relocations (n=625) for foraging sea otters (high quality ≤ 0.5 km) of all sex and age classes from August 2007-April 2010.

APPENDIX A

Sea otter tracking 2007-2010

The purpose of Appendix A to the Final Report: MONITORING SURVIVAL AND MOVEMENT PATTERNS OF SEA OTTERS (*ENHYDRA LUTRIS KENYONI*) IN KACHEMAK BAY, ALASKA AUGUST 2007-APRIL 2010 is to provide supplemental information on the monitoring methods for VHF radios which were internally implanted in free-ranging sea otters in Kachemak Bay, Alaska. We have provided information on techniques that worked well, those that tried and worked less well, and detail on data handling over the 3-yr monitoring period.

Monitoring Equipment

Airplane Type

Aerial tracking was completed by Jose Decreeft at Northwind Aviation. From 7/31/07-2/21/08, Oriana Badajos accompanied the flights as the primary data collector. Thereafter, the pilot was trained to collect data without an observer. During the ice-free periods on Beluga Lake, we used a Bird Dog (Cesna L-19) on floats as the primary radio-tracking aircraft. During winter, we used a Cesna-185 (and later a Cesna-206) because flying on amphibious floats was necessary. For six weeks in the winter of 2007, before the pilot was able to acquire amphibious floats, we flew the Bird Dog on wheels at a high elevation to record the presence/absence of mortality signals, but were unable to fly low and track the signals. Over a long period of tracking study animals, it is not uncommon to need to use different types of aircraft for monitoring and two common factors that affect this include periodic aircraft maintenance and the ice-free season for landing on fresh water for float planes. We did not detect a difference in the tracking efficiency between the Bird Dog on floats, which has a slow stall speed, and the Cesna 185 or 206 which have a higher stall speed. This may be in part due to the extensive experience level of the pilot who has been doing radio telemetry studies for almost 20years.

Skiff-based Tracking

Our skiff-based tracking efforts were minimal during the course of this study. We used an 18-foot rigid-hulled inflatable and a 26-foot Boston Whaler as tracking vessels. We used a single 4-element Yagi antenna (ATS) and an R4000 ATS receiver for monitoring. Some techniques for tracking include mounting the antenna on a long poll for better range (mount it in such a way that you can easily rotate the direction the antenna is pointing). In the 18-foot vessel, we attached the antenna to a tripod and extended it as high as possible and saving the tracker from having to hold the antenna the entire tracking time (there were space limitations on the smaller skiff). If extensive radio tracking is to be done by skiff, we recommend that 2 4-element Yagi antenna are attached to fixed poles at about 30 degrees on the starboard and port sides of the vessel with high quality co-axial cables (to reduce interference) to a single radio receiver with a right and left switch box attachment.

Antennas & Cables

Two 4-element Yagi antennas (ATS) were mounted on the airplanes with RG400 coaxial cables running to a two-way antenna switch box (Telonics). We originally started with RG58 cables (ATS), but when these cables wore out, we ordered RG400 coaxial cables which are aviation electronics grade. We found the RG400 coaxial cables to be noticeably more sensitive and recommend RG400 over the RG58. The coaxial cables were replaced approximately every year, when interference increased due to loss of shielding. If background noise levels increased while radio tracking, ACF-50 (Lear Chemical, INC) anti-corrosion lubricant or DC4 (Dow Corning) silicone grease was used on the coaxial connectors. We connected the right and left wing cables through a switch box that allowed us to hear signals from both antenna or right and left independently.

We tried various antenna configurations including: horizontal, vertical, and both horizontal and vertical (with 4 antennas, two on each side). A horizontal configuration with the receiving end tilted down approximately 30° was found to be optimal and also had less wind resistance and shaking during flight. Having 4 antennas (2 on each side) was found to be counterproductive in that it increased the amount of background noise. To compensate, the gain had to be turned down and the tagged otters were therefore harder to hear. The vertical configuration worked but appeared to have a more limited range than the horizontal positioning, and there was also a larger amount of drag during the flight.

VHF Receivers (Advanced Telemetry Systems)

Our primary monitoring receiver was a R4000 ATS receiver for aerial tracking of study animals. Because of the long scan time to search through 44 frequencies, we tried using two receivers scanning at the same time, but found that the interference from adding a second receiver diminished the signal strength. We found that using only was receiver was optimal.

We explored the use the newer digital R4500S for routine tracking in the aircraft and found it less optimal than the older style R4000 receivers for the following reasons: the dials on the R4000 are set up in a better configuration for manual adjustments while radio tracking than the R4500S, the key pad on the R4500S was cumbersome to adjust on the fly, and the digital display required more visual attention to managing the receiver and took time away from observing otters.

We used an R4500S receiver as a data logger to collect presence/absence data for our study animals. The system was set up to monitor the Mud Bay area which had high densities of tagged study animals during the fall and winter months. The set up included a 3-element folding Yagi antenna was mounted on a 15-foot pole facing Mud Bay and connected to the receiver with a RG58 coaxial cable and a test transmitter to ensure data was being captured on the receiver. The R4500S performed very well for this purpose.

Global Positioning System

During each radio tracking flight, a hand-held Garmin GPSMap 76CS was used with a GA27C GPS antenna kit. The GPS preserved the trackline of the monitoring effort and each study animal location was collected as a waypoint and recorded on a data sheet. The GPS antenna kit was critical to recording accurate locations of tagged otters. We used two GPS's to facilitate the data transfer. This way, the pilot was never waiting for data to be downloaded and had an empty GPS ready to go when conditions allowed.

Search Effort Monitoring Strategies

Study Area

The total study area was approximately 226,421 acres and was searched approximately three times per week (unless there were aircraft or weather delays). From 07/31/2007 – 05/03/2010, we completed 431 aerial tracking flights totaling 931 hours and 125,525 km flown searching for tagged otters.

Missing study animals were searched for with both dedicated and opportunistic flights outside of the study area on the eastern side of Cook Inlet (n=42) as well as opportunistic flights that occurred on the western side of Cook Inlet (n=7). The opportunistic flights were at no cost to the project because our pilot was able to leave the receiver scanning when conducting flights for other customers in Cook Inlet. Such opportunistic flights recovered a dead tagged otter outside of the study area as well as tagged otters further out towards Cook Inlet than normally would be searched. In total, 9,421 kilometers of track line outside of the study area were searched.

Monitoring Strategy

The primary purpose of the study was to monitor the survival of sea otters in an area that had been designated as an Unusual Mortality Event (under the Marine Mammal Protection Act; 109h) and to recover any study animals that died during the course of the study. All routine radio tracking was done by aircraft and monitoring was initiated as soon as study animals were released after surgical implantation (late July 2007) and tracking continued through 03 May 2010. The target relocation frequency was one time per week throughout the effective battery life of the transmitters. For each location we recorded, date, time, location (GPS latitude/longitude), group size, location quality, behavior, and reproductive status (pup/no pup for females). We classified the relative accuracy of each location as high quality (≤ 0.5 km) or low quality (>0.5 km) and visually confirmed the study animal's location when feasible (by seeing flipper tags or strong pairing of radio signal with animal behavior).

To obtain a weekly location on each study animal required more than one flight per week in this study; even with this search intensity the average relocation was 12 days per study animal. At the beginning of the tracking week, the frequency of all study animals were loaded into an ATS (R4000) receiver and each frequency was deleted after the animal was located. By deleting those already found, more effort was given to finding those that need to be detected. The majority of the tracking was conducted at about 500 feet. With the exception of territorial males, most study animals were located in open water habitat (> 1km from shoreline). Wind and wave height appeared to strongly influence signal strength and our ability to locate otters in open water habitat.

One strategy for monitoring for missing study animals involves bracketing the radio frequency in case there has been some drift in the transmission (or the tracker is using multiple receivers that have different optimal signals). In our study, we did not bracket frequencies; we found the frequencies to be quite stable at the beginning of the study and only slight shifts in optimal frequencies at the end as the transmitter batteries began to die. With a tracking weekly relocation frequency, there were too many frequencies to listen to (44) along with bracketed frequencies. However, on searches outside our main study area, we did bracket for external searches when listening for missing study animals.

Another approach for monitoring for missing animals was to fly the coastline at low tides to search specifically for mortality signals that would otherwise be covered during the high tide. Kachemak Bay has extreme tides (28-foot range) and it is possible for a study animal to die and have their signal be "unavailable" during high tides when the carcass is covered by water. We instituted low-tide searches of the study area coast-line when animals were missing. This resulted in the recovery of two dead otters that otherwise would not have been found at high tide.

Radio-frequency Interference

During 2008, we discovered that there were tagged cranes in our study area using the same VHF frequencies as the otters. We found that although we had federally approved VHF frequencies for our study area in Alaska, the Principle Investigators in the crane study used federally approved frequencies for California (even though many cranes were captured and tagged in Homer, Alaska). There was no communication between the studies until our pilot tracked a crane instead of an otter. The cranes migrated to Alaska in the spring, and returned to California in the fall. In total, 15 of our 44 tagged sea otters held VHF frequencies that overlapped with tagged cranes. The crane radios had a pulse rate of 40 bpm (80 bpm mortality) as opposed to the otters that had a pulse rate of 55 bpm (110 bpm mortality). This helped us to distinguish cranes from otters, but it was a subtle difference. Behavior and location also helped to distinguish the two; nevertheless, we did accidentally track cranes during the course of the study. If the crane researchers accidently tracked sea otters, we were unaware of it.

We had some interference with a radio tower on a single frequency but did not have any other problems with radio interference during the course of the study.

Tag retention/loss

Each otter was tagged with a color-number coded plastic tag in the interdigital space on the hind flipper. During aerial tracking in year one, we frequently identified the tagged otter by the presence of the colored tags. By year two and three, many of these tags were noted missing. During the last 4 months of the study (since 1/1/2010), only 9 of 38 otters had at least one tag known to be visible. Tag retention depends on multiple factors including animal behavior and how the tags were applied. At the time of capture, the lead veterinarian noted that several of the study animals had bite wounds on the hind flippers which indicated high intraspecific interaction among otters in this area. We elected to do a single rather than double flipper punch in applying the tags.

Aerial vs. Boat Tracking

When the study began in August 2007, we averaged 4.6 otters/hour (max 7.6, min 3.3) by aerial tracking. During the third year of the study, we averaged only 2.5 otters/hour (min 1.9, max 3.0). Surprisingly, the transmitters were able to broadcast for close to three years, as the manufactured stated life span was only two years.

Minimal boat tracking was conducted during this study, primarily because it was found to be fairly ineffective (in the recovery of study animals, personnel time, and boat fuel). During the summer of 2008, study animals were tracked to assess diet (none were re-located while foraging) and in 2009 to assess tag loss. We tracked otters by boat 4 times and averaged 0.8 otters/hour (max 1.2, min 0.3). Kachemak Bay poses a unique challenge in that the otters utilize a lot of open water space. It was clear that aerial tracking was necessary to be able to assess survival and aid in the recovery of dead study animals.

Remote Monitoring by Datalogger

Starting on 11/24/2008, we used a R4500S ATS receiver to collect stationary data in Mud Bay, Kachemak Bay; an area with a high density of tagged sea otters. A 3-element folding Yagi antenna was mounted on a 15-foot pole facing Mud Bay and connected to the receiver with a RG58 coaxial cable. On average we heard 22 of 44 tagged otters per month on the Mud Bay receiver (max 29; min 9). This receiver was particularly useful for supplementing the aerial tracking. In many instances, we would not be able to locate an otter for a few weeks, but the stationary receiver would have logged its presence in Mud Bay. We therefore knew that the otter was still alive. The receiver was also in close proximity to a collection beach. A dead tagged otter washed up on this beach and its mortality signal was picked up by the stationary receiver.

The receiver settings were as follows:
Stationary Data
Fixed Pulse Rate
Scan Type: Pattern Matching
PR1: 55
Tolerance 1: 10
PR2: 110
Tolerance 2: 10
Time Out: 10
Scan Time: 10
Store Rate: 60
Table number(s): 1
Antennas: 1
Reference Frequency Used: Yes
Reference Frequency: 164780
Reference Freq Store Rate: 60

Data

Our original intent was to use the national database set up by Tim Tinker, USGS and UC Santa Cruz (Wild Sea Otter Database "WSOD"). We soon found that our almost entirely aerial-based tracking scheme did not often fit the primarily land-based monitoring database structure in WSOD. This became further complicated as there is only one person who can modify the master WSOD and he was often very busy and unavailable for small changes to the structure. Thus, we took many aspects of the WSOD and created a data structure that more accurately reflected the data being collected in our study. The Kachemak Bay sea otter database was set up using the same codes as the national database with the intent of importing our data into WSOD when the data collection was complete.

We used a Garmin GPS to collect raw data, which were then downloaded into Mapsource (Garmin Ltd.), exported to excel for formatting, and finally imported into the Kachemak Bay sea otter database (Access). This allowed us to import otter ID, date/time, and Lat/Long without having to retype the information. The rest of the data collected on the tracking datasheet were entered directly into the Access database. Detailed step-by-step instructions on data downloading and entry are presented below.

To create weekly summaries in Mapsource:

- Open raw data file and save as:
  - YYYYWeek_MM_DD-DD.gdb in the following location: O:\RESEARCH\Data\SeaOtter\Tracking\WeeklyReports
  - (example: 2008Week_05_12-18.gdb)
- Export mapsource tracks to GIS:
  - Connect GPS to computer (make sure empty memory for tracks)
  - Open ArcMap, need to have MxGPS (ArcMap extension); http://www.mxgeo.com/
  - Open Mapsource
    - Send one trackline back to the GPS, using "ACTIVE LOG 001" (title that was originally given)
    - If you use another title, the GPS will automatically truncate the track
    - If you send multiple tracks, they will be merged as one
  - Go to ArcMap, select the "GPS unit" tab, select "download", "get tracks from gps"
  - Save as: YYYY_MM_DD.shp
- Preparing waypoint data for export:
  - Use the datasheet. In Mapsource, rename the waypoint number with the otter number. For example, Otter #19 was heard at the waypoint 001. Rename 001 as 19.
  - If you get confused or make a mistake, you can always go back to the raw data download to track down errors.
  - Sometimes there are more than one otter found at a waypoint. I re-label the waypoint with all of the otter numbers, separated by a comma. Example: 01,08,15 (all found in one location)
  - Sometimes there are extraneous waypoints. When you are sure they are extraneous, delete these so that every waypoint is labeled with an otter number.
  - When finished, use the datasheet to check what you've done as it's easy to make a mistake.
  - Lat/Long needs to be in decimal degrees for the database. If you need to switch to Degrees Minutes to compare to pilot's notes, go to Edit/preferences/position tab/select the grid from the pull down menu.
    - Lat/Lon hddd.ddddd (for database)
    - Lat/Lon hddd°mm.mmm' (pilot records in this format)
    - Datum should always remain WGS84

Export waypoint data to Excel:

- Start an excel spreadsheet with the following headings:
  - Flight ID, DateTime, Otter, Lat, Long, Comments, Alt
- Copy and paste waypoints from Mapsource, then drag columns into the correct order
- Format the columns:
  - Select the altitude records that you just pasted.
  - Hit Ctrl+F (find & replace)
    - Find what: “ft”
    - Replace with: (leave blank)
    - Select replace all. They should all become numbers
  - Lat/Long will all be in one column. Move it to the comments column for now.
    - Go to the lat column, select ‘Insert’ and “function’. Select the category “text” and then “Left”
    - There should be a pop-up box called ‘function arguments’
      - Text: select the lat/long cell that you wish to separate
      - Num_chars: 9
      - Go to the bottom right corner of the cell until you see the + sign
      - Drag the formula down to the rest of the column
      - With all of the cells highlighted, hit ‘Ctrl+C’ to copy, then Right-click and choose ‘paste special’
      - Paste = values
      - Hit Ctrl+F
        - Find= “N”
        - Replace= (leave blank)
        - Replace all
    - Do the same for the Long column, except select insert/function/text/right
      - Num_chars=10
      - Also, when you Ctrl+F
        - Find= “W”
        - Replace= -
        - Replace all
    - Now you have Lat/Long in separate columns in decimal degrees.
      - Example Lat: 59.59534
      - Example Long: -151.16674
      - You can delete the original Lat/Long data that are all in one cell.
  - When more than one otter was found at a location:
    - Insert a new row so that each otter has its own record
    - Copy & paste the date/time; lat/long & altitude info
- Sort records by date/time
- Now, before records can be entered into the database, you must enter the flight information in Access

Importing data into Access Database

- Located at: O:\RESEARCH\Data\SeaOtter\" SeaOtter.mdb"
- Select the 'forms' tab. Open the 'survey' form. This is the main data entry form.
- Go to a new record, put in the flight information
    - Date time start, date time end, weather, etc
- Once the flight info has been entered, record the flight ID number (auto number)
- Go back to the excel spreadsheet and enter the flight ID number for the corresponding days.
- Select all of the records that you wish to import into the database. Hit Ctrl+C
- Go to the database, (make sure the form is closed), go to the 'table' tab, and open the 'tracking' table.
- Scroll to the very bottom of the table. The last row will be blank.
    - Highlight the following cells in the last row: flightID, date, otterID, Lat, Long, comments, alt.
    - Hit Ctrl+V to paste your records.
        - Make sure you are not copying over any other records!!
- Close the table, and open the 'survey' form.
    - Go to the flight whose data you are entering. Date, lat/long, otter#, and frequency should already be listed.
    - You can now enter data off of the datasheet into the form.

Database/Datasheet codes

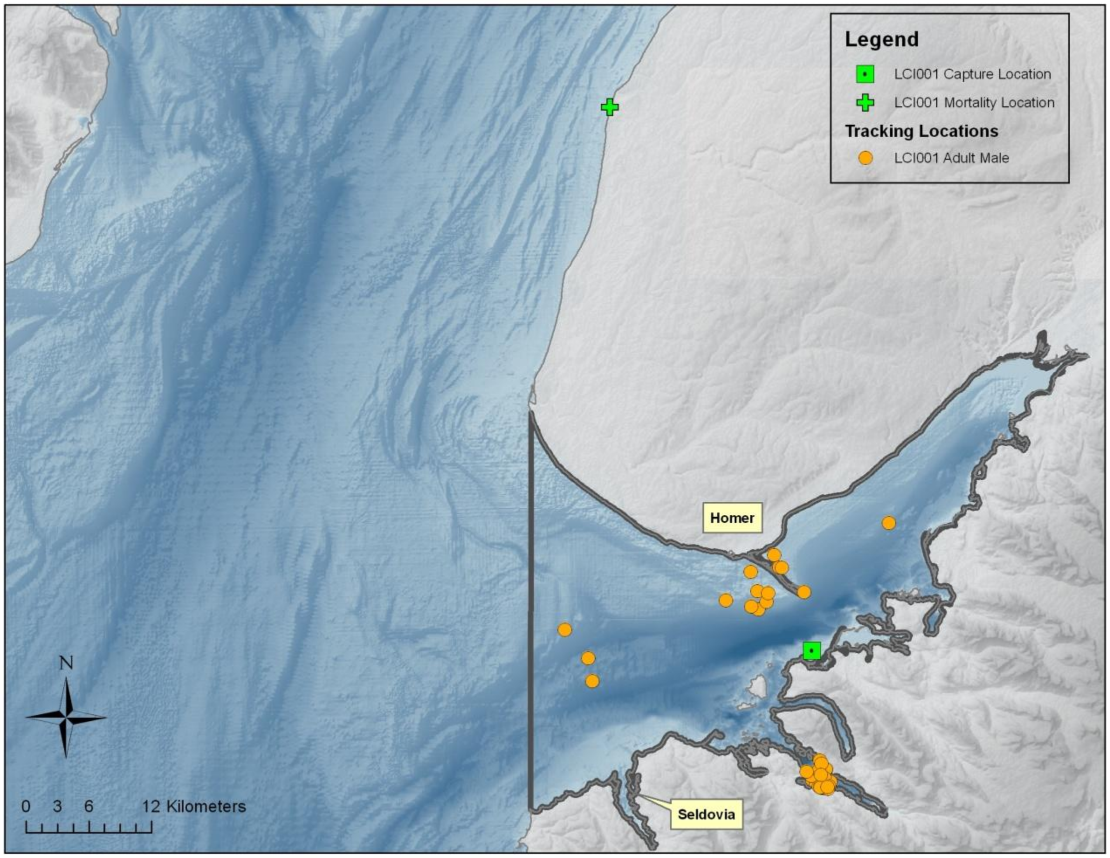
- Datasheet codes:
  - Date=tracking date
  - Last seen=date the otter was last located
  - Otter=otter ID # (1-44)
  - Frequency=Radio frequency of tag (164-165 mHz)
  - Alive= Yes/no (Is the otter alive)
  - Waypt=Waypoint position stored in the GPS
  - General Location=General description of where the otter was found (i.e. Mud Bay)
  - Lat, Long= Lat/Long of otter's location (datum=WGS84)
  - Tags?=Did the observer see the tags (Yes/No). If yes, observer should circle which tag they saw in the 'tags' column.
  - Active?=(A=active; I=Inactive; U=Unknown)
  - Behav=(F=Foraging; R=Resting; H=Hauled out; S=Swimming; U=Unknown)
  - Group=Number of otters in group including tagged otter
  - Pup=(NV=No View; None=Female with no pup; Pup=Female with pup)
  - Comments=A place for observer to write comments. I keep the pup & crane status updated each week
  - Tags=As of capture in August 2007, (A=Adult; SA=Subadult; J=Juvenile; P=Pup; M=Male; F=Female). The second line refers to the tag colors on the otter hind flippers (Right/Left)
- To find out the database codes, go to the tables tab and open one of the tables.
  - Change to design view- each field will have a code description
- Data Entry form (flight data)
  - Date/Time start of survey
  - Date/Time end of survey
  - Sea, Swell, Wind Direction, Wind Speed, Air Temp: Descriptions are listed on datasheet
  - Sky: combo of the CC & precip fields on the datasheet.
  - Observer: Defaults to Jose Decreeft (JD)
  - Check?: has the data entry been checked (best if by dif person)
  - Type of Survey: (Plane, boat, land, etc) It will default to plane

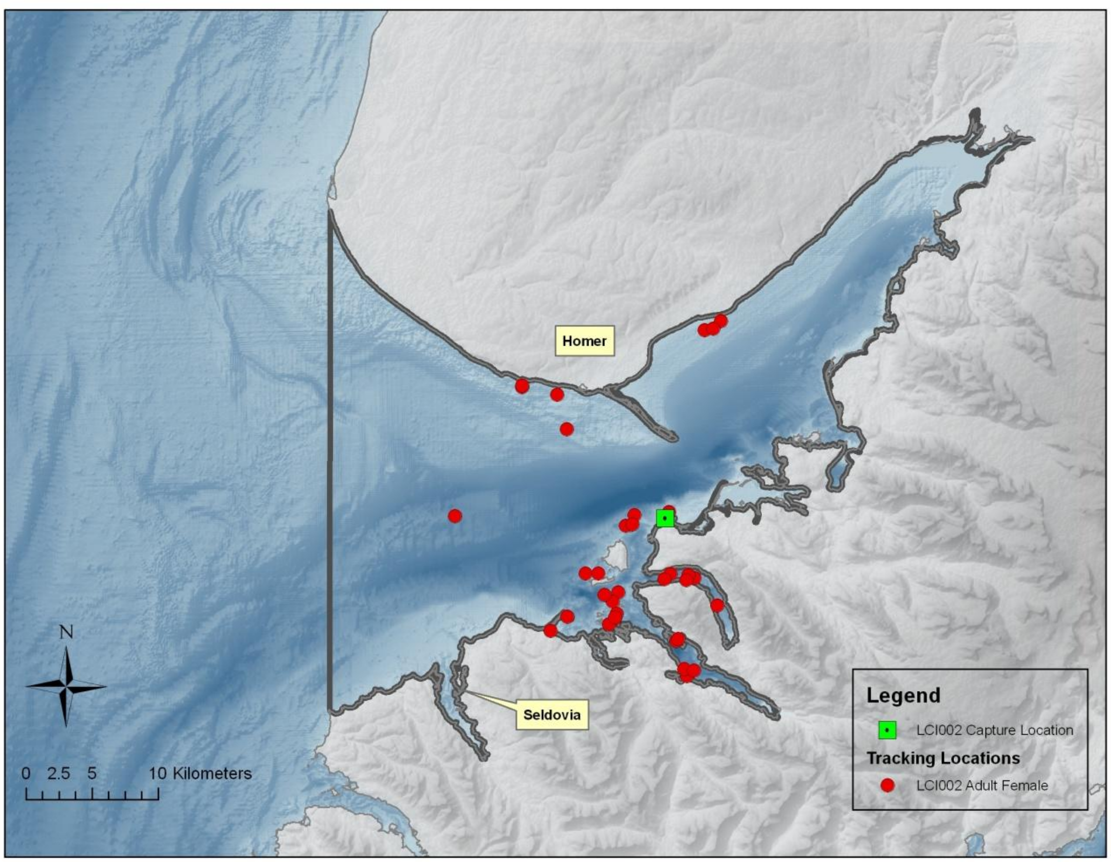
- Data Entry form (tracking data):
    - You will import the flight ID; date/time; Lat/Long; Frequency; and OtterID as described above.
    - Enter the location description
    - Tags= N=no tags seen; 1=1 tag seen; 2=both tags seen; Y=tags seen, but unknown which one(s)
    - Active=A, I, or U (same as datasheet)
    - Behav=F, R, H, S, U (same as datasheet)
    - Group=Number of animals (same as datasheet)
    - Fix type=Generally going to be ‘A’ or ‘T’. We use ‘A’ for poor locations, with no visual; and ‘T’ for good locations. Generally, if there is a group size listed, I use ‘T’. If no visual was made on the group, or observer notes that it is a poor location, I use ‘A’
    - Age/Sex will appear automatically and does not need to be touched
    - Status=
        - If male, I always use ‘Y’ (Male, unknown status).
            - After many locations, I go back and decide if it was territorial or not and change to ‘M’ (non-territorial) or ‘T’ (territorial)
        - If female, then the choices are None, NV, PL, PS, PU (None=Female, no pup; NV=Female, no view; PL=Female, with large pup; PS=Female with small pup; PU=Female with pup of unknown size)
    - Write any pertinent comments
- There is a category in the ‘Tracking’ table called ‘ObsAge’. Once I have a few months of data, I go back and fill this in. It is the age of the animal at resight. For example, if a pup was captured and tagged, it will become a subadult at (1-5 years), and an adult (>5 years) later in the study.

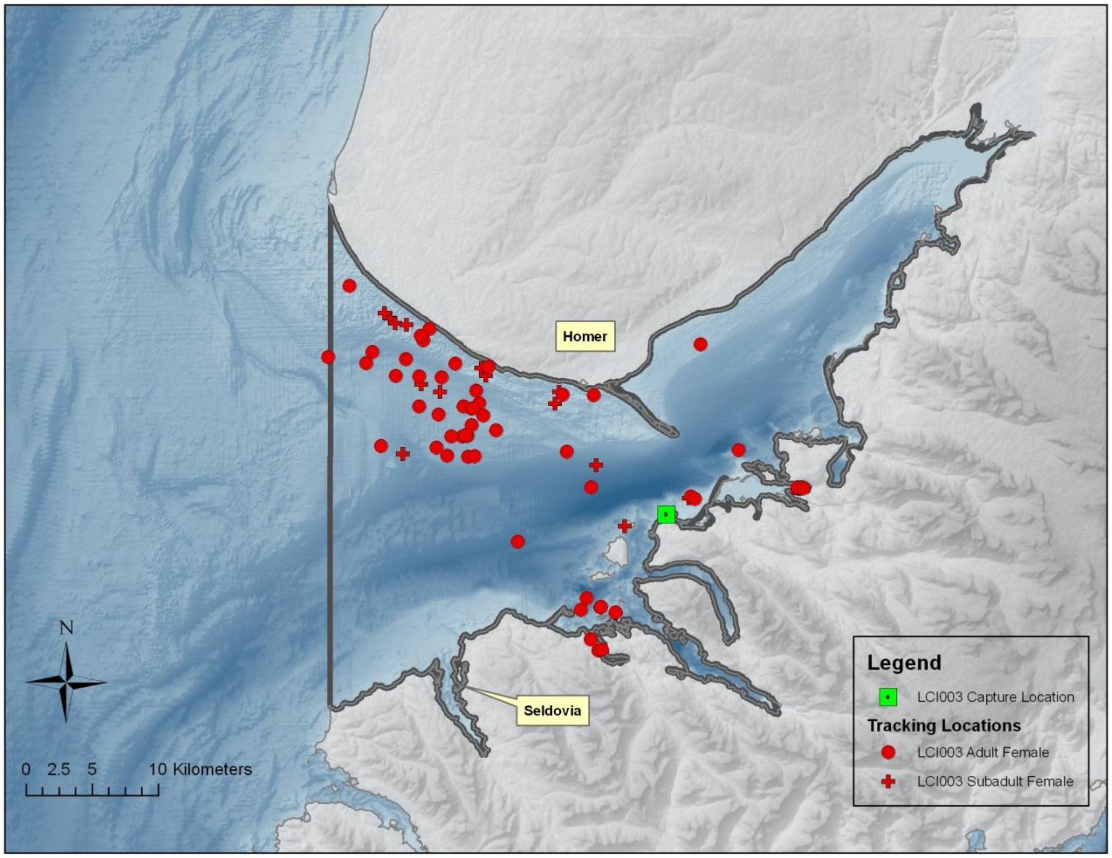
APPENDIX B

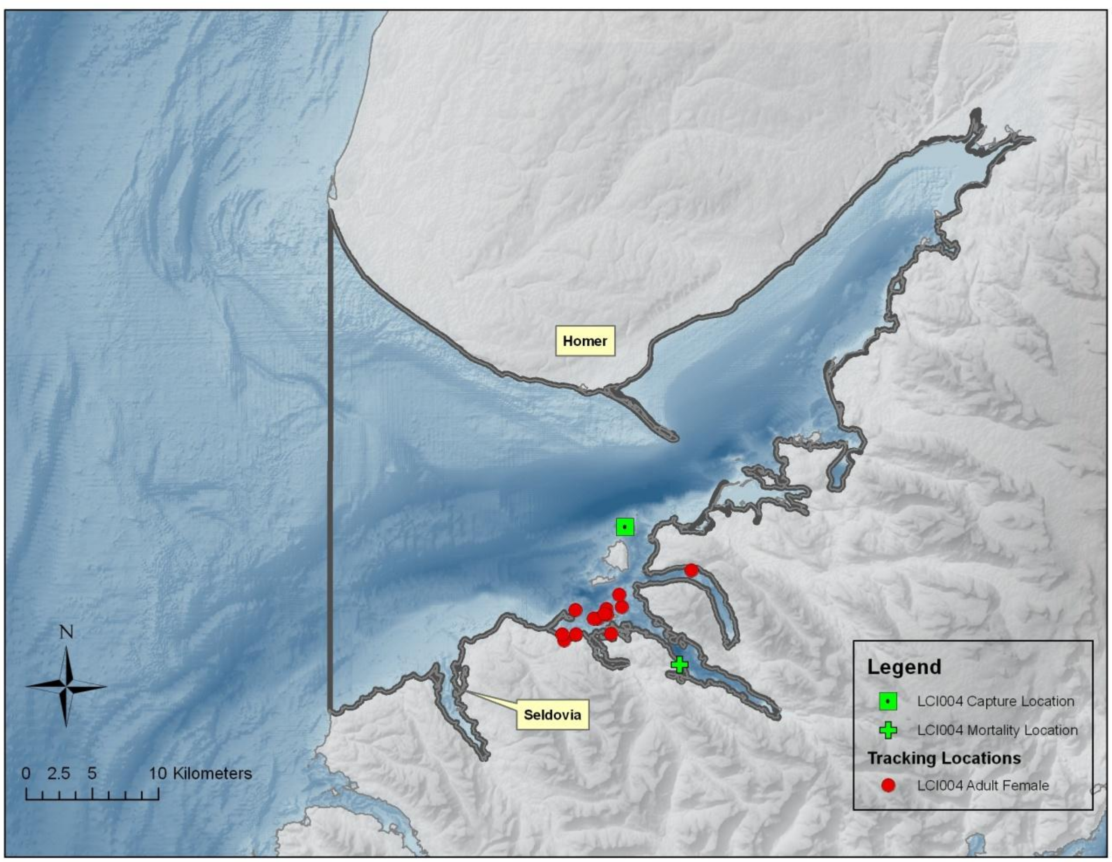
Sea otter tracking 2007-2010

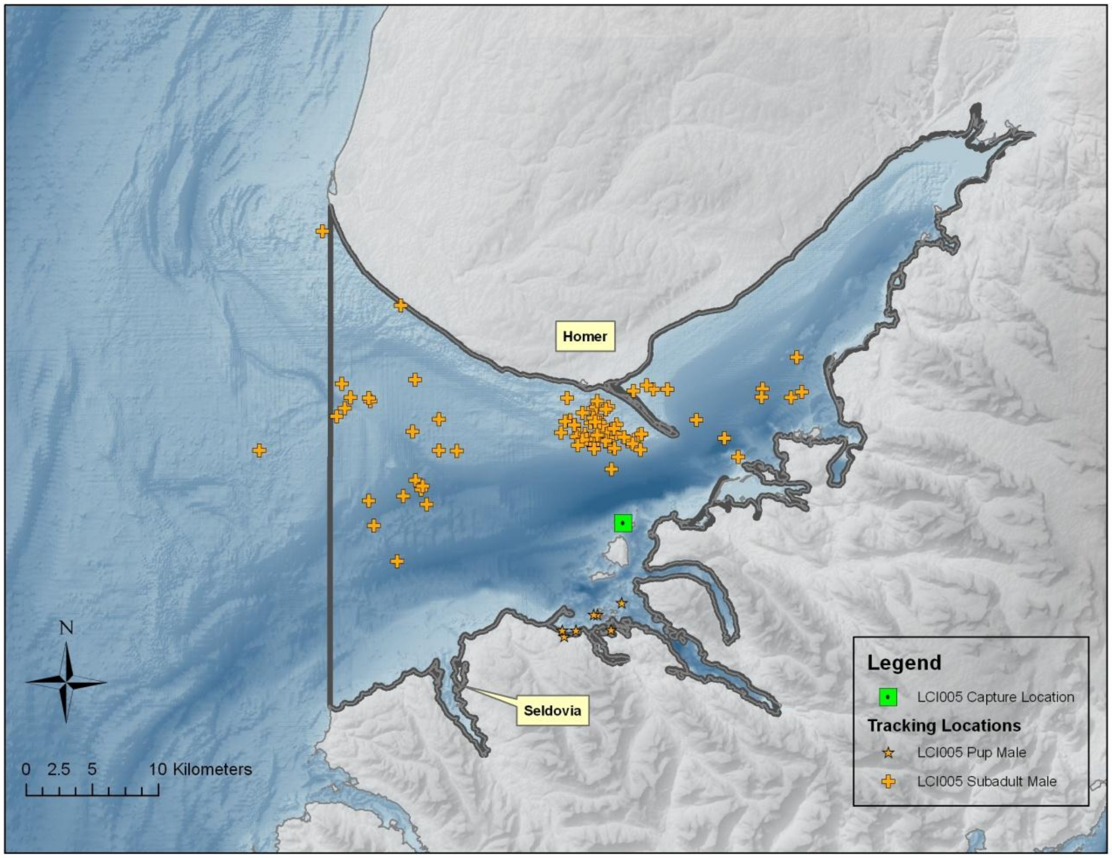
The purpose of Appendix B to the Final Report: MONITORING SURVIVAL AND MOVEMENT PATTERNS OF SEA OTTERS (*ENHYDRA LUTRIS KENYONI*) IN KACHEMAK BAY, ALASKA AUGUST 2007-APRIL 2010 is to provide supplemental information the high quality locations of individual study animals which were implanted with VHF radio transmitters and monitored throughout the study period in Kachemak Bay, Alaska.


Legend
LCI001 Capture Location
LCI001 Mortality Location
Tracking Locations
LCI001 Adult Male
Homer
Seldovia
N
0 3 6 12 Kilometers


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI002 Capture Location
Tracking Locations
LCI002 Adult Female


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI003 Capture Location
Tracking Locations
LCI003 Adult Female
LCI003 Subadult Female


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI004 Capture Location
LCI004 Mortality Location
Tracking Locations
LCI004 Adult Female


Homer
Seldovia
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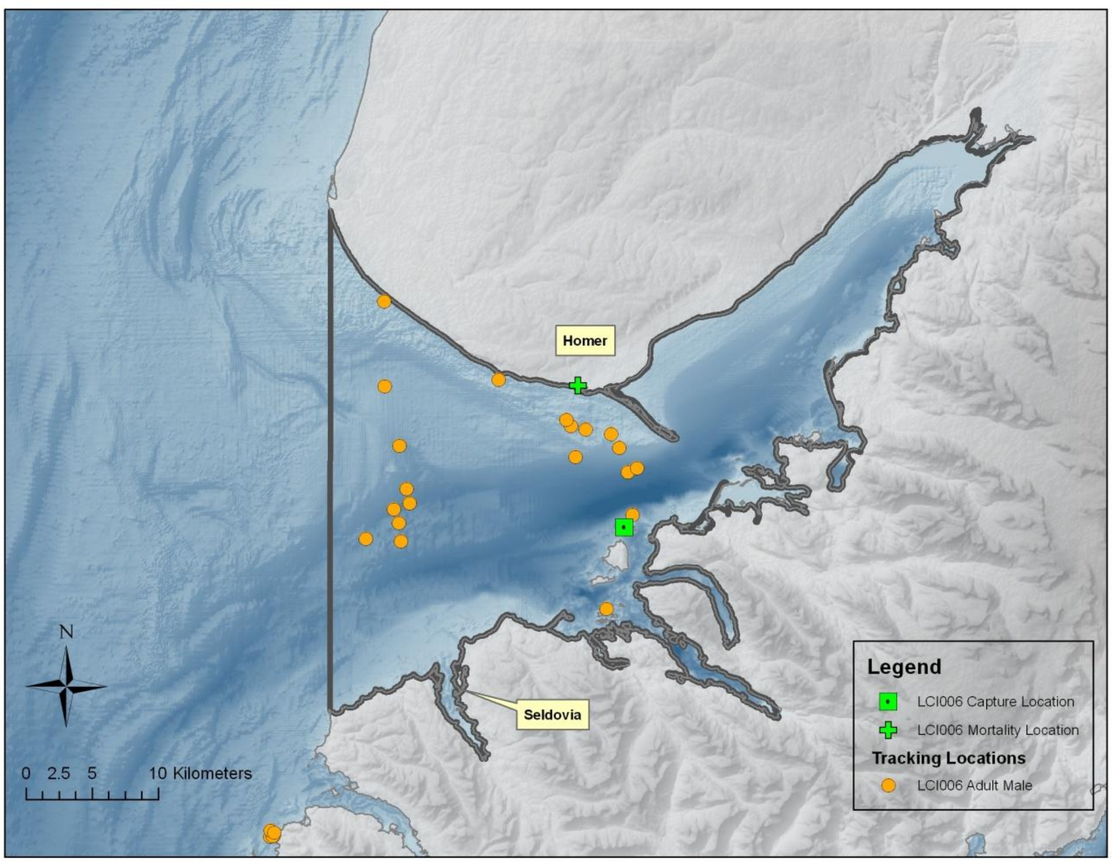
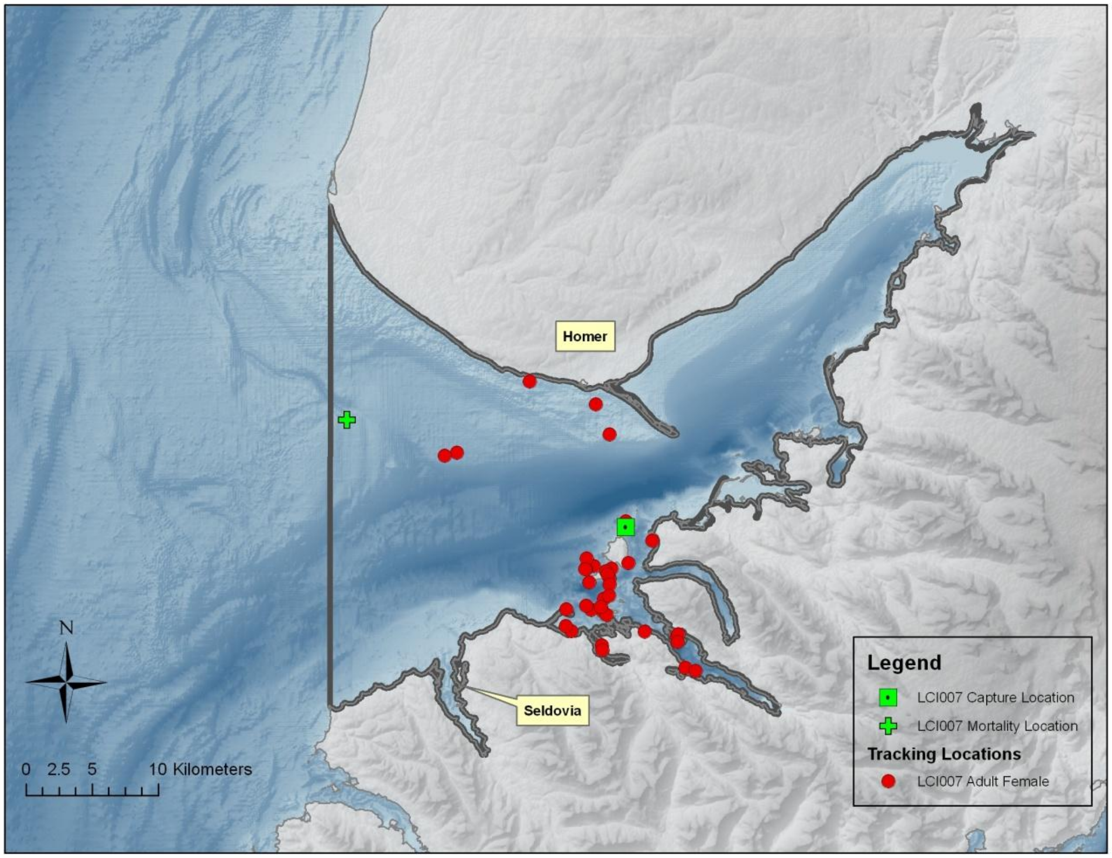
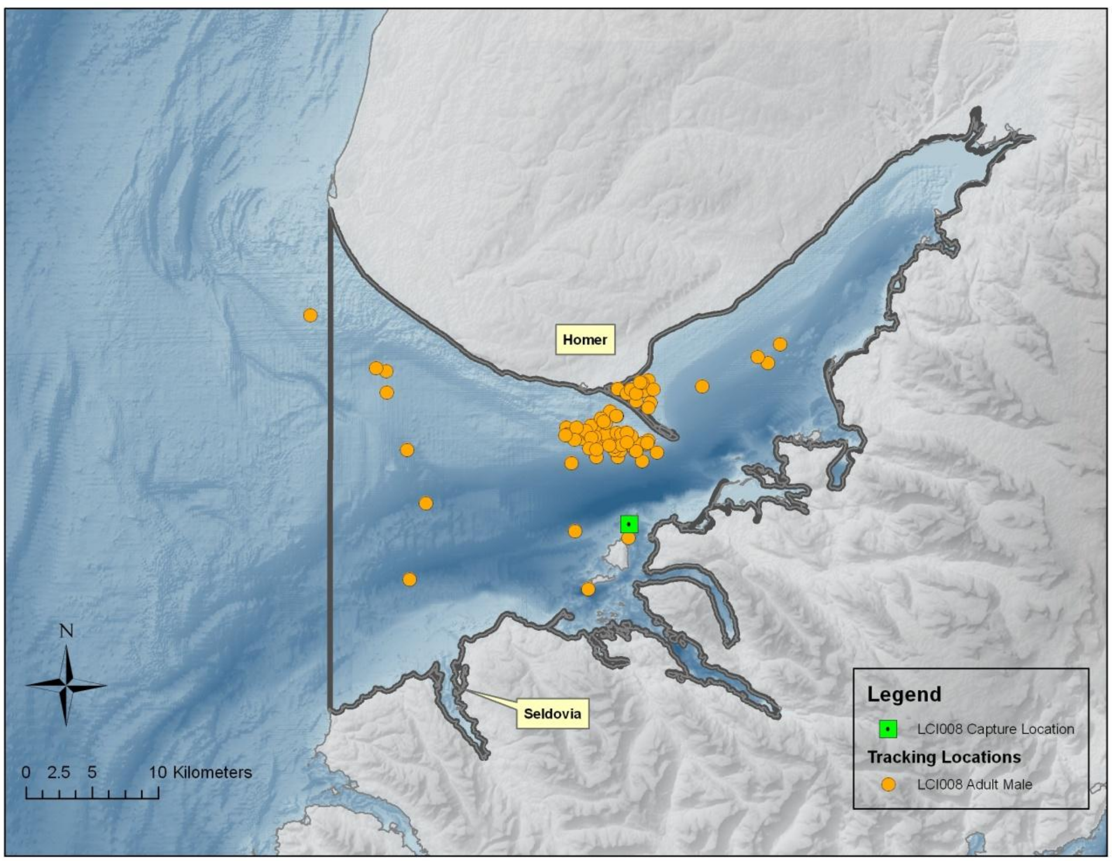
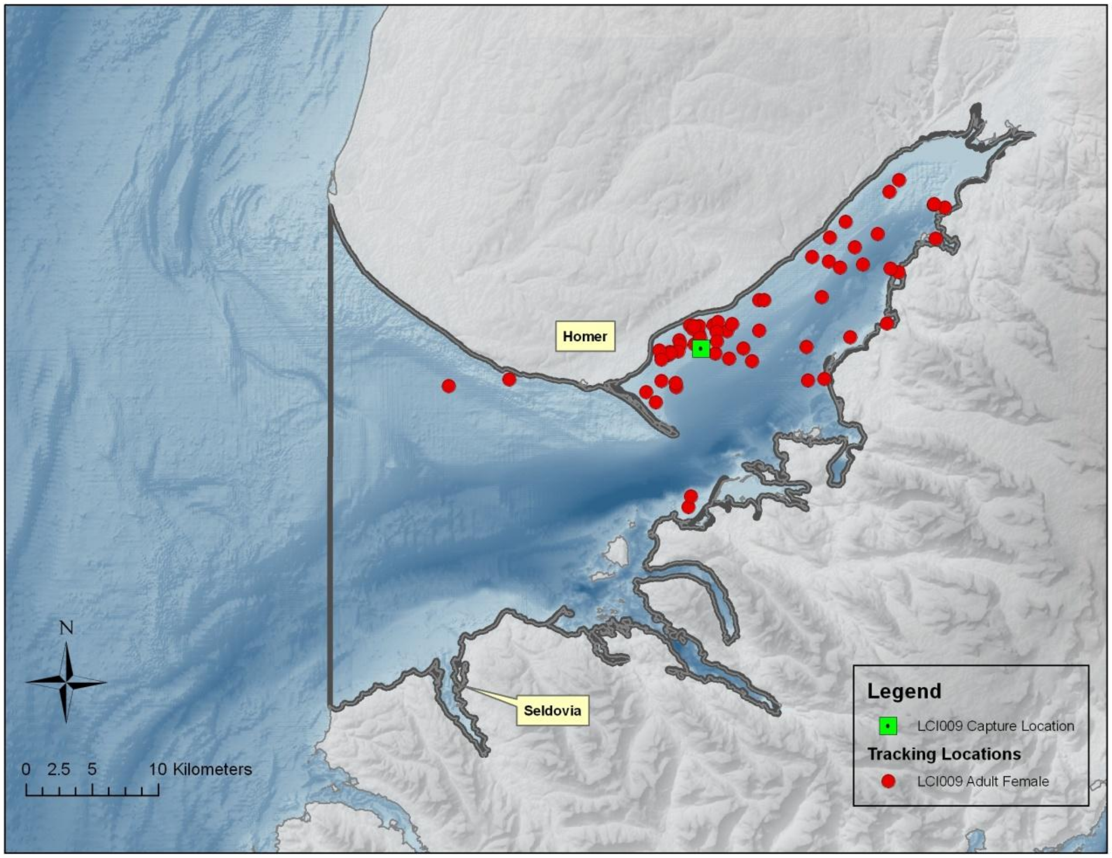
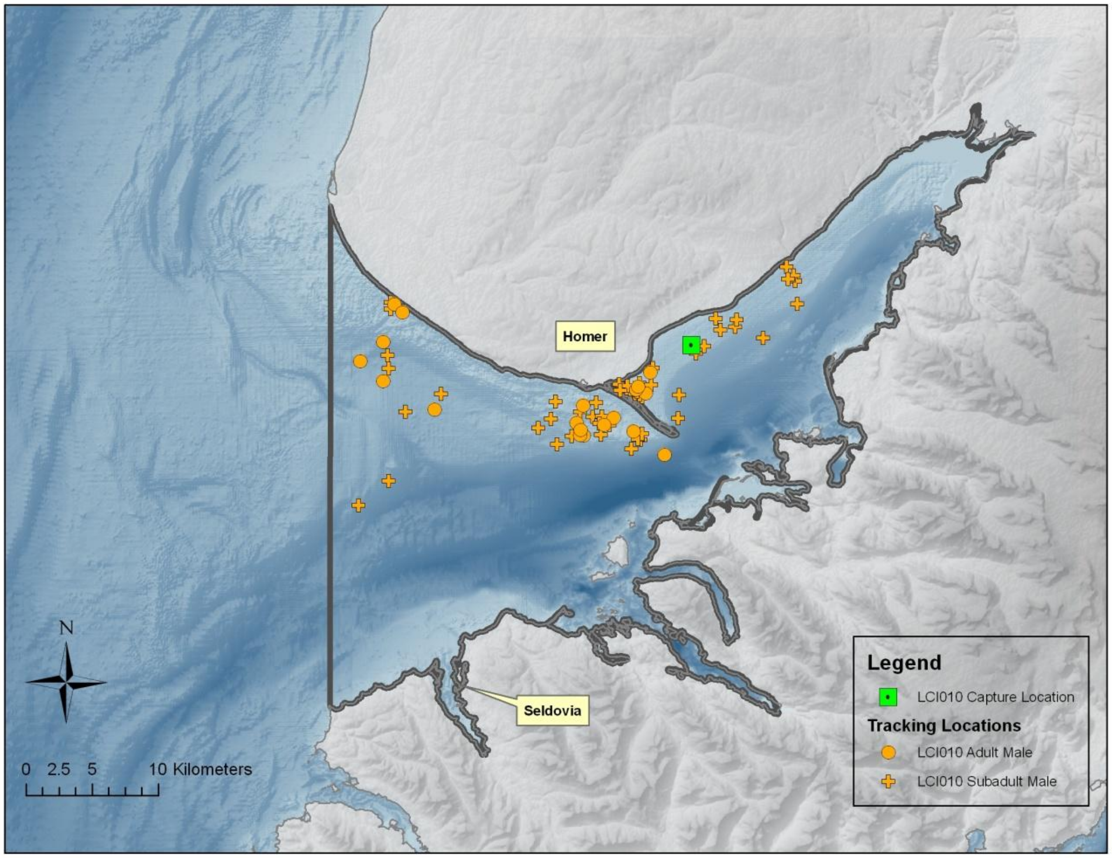
Legend
LCI005 Capture Location
Tracking Locations
LCI005 Pup Male
LCI005 Subadult Male

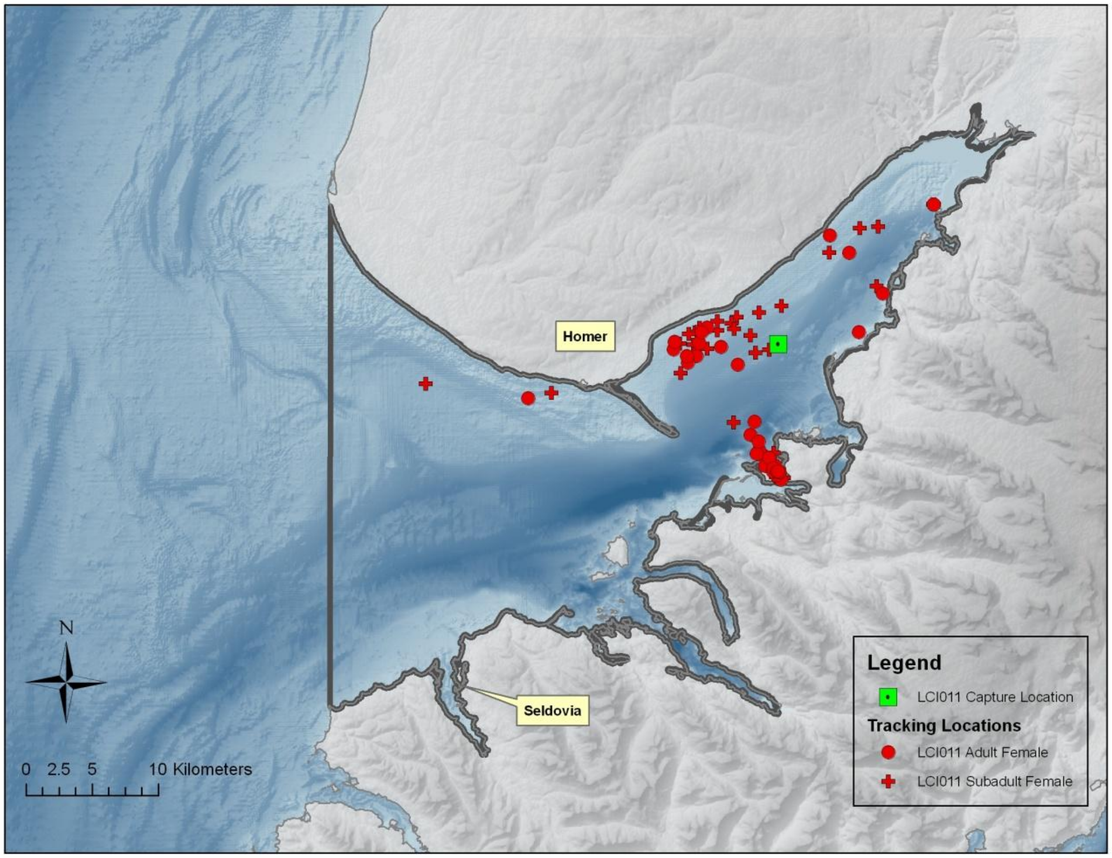

Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI006 Capture Location
LCI006 Mortality Location
Tracking Locations
LCI006 Adult Male

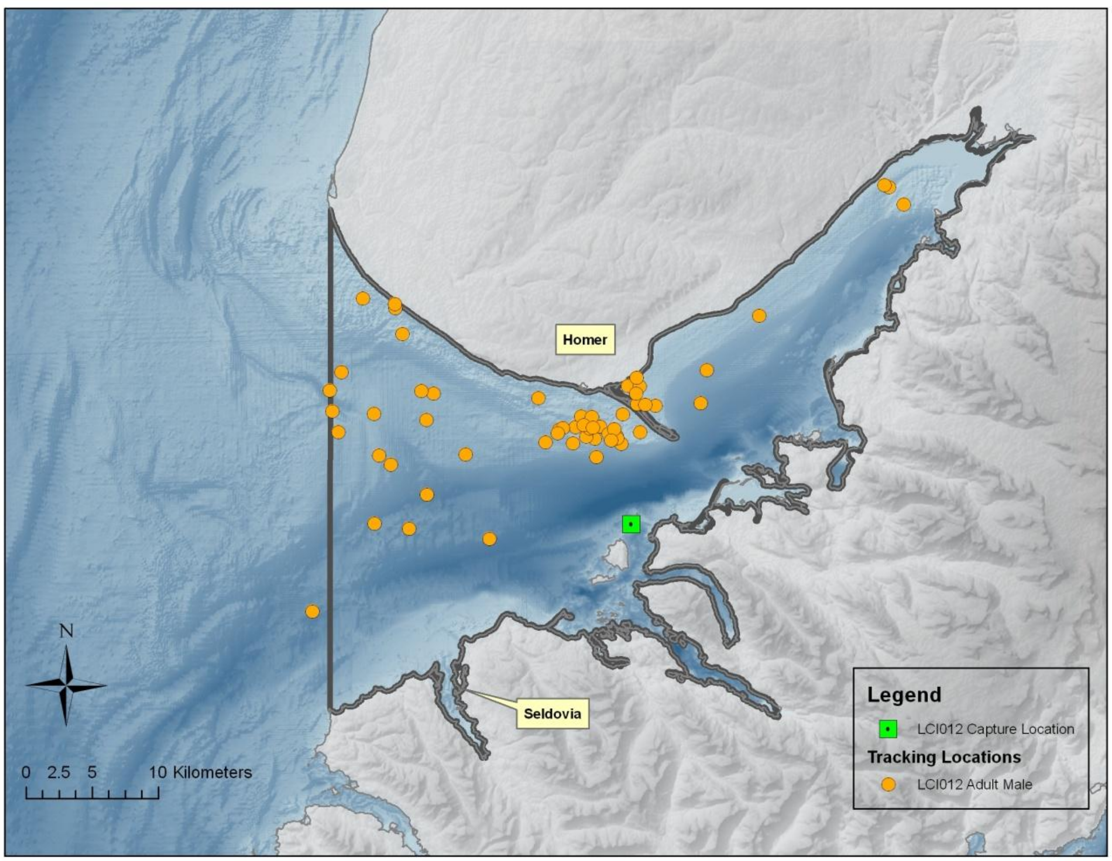

Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI007 Capture Location
LCI007 Mortality Location
Tracking Locations
LCI007 Adult Female


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI008 Capture Location
Tracking Locations
LCI008 Adult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI009 Capture Location
Tracking Locations
LCI009 Adult Female


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI010 Capture Location
Tracking Locations
LCI010 Adult Male
LCI010 Subadult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI011 Capture Location
Tracking Locations
LCI011 Adult Female
LCI011 Subadult Female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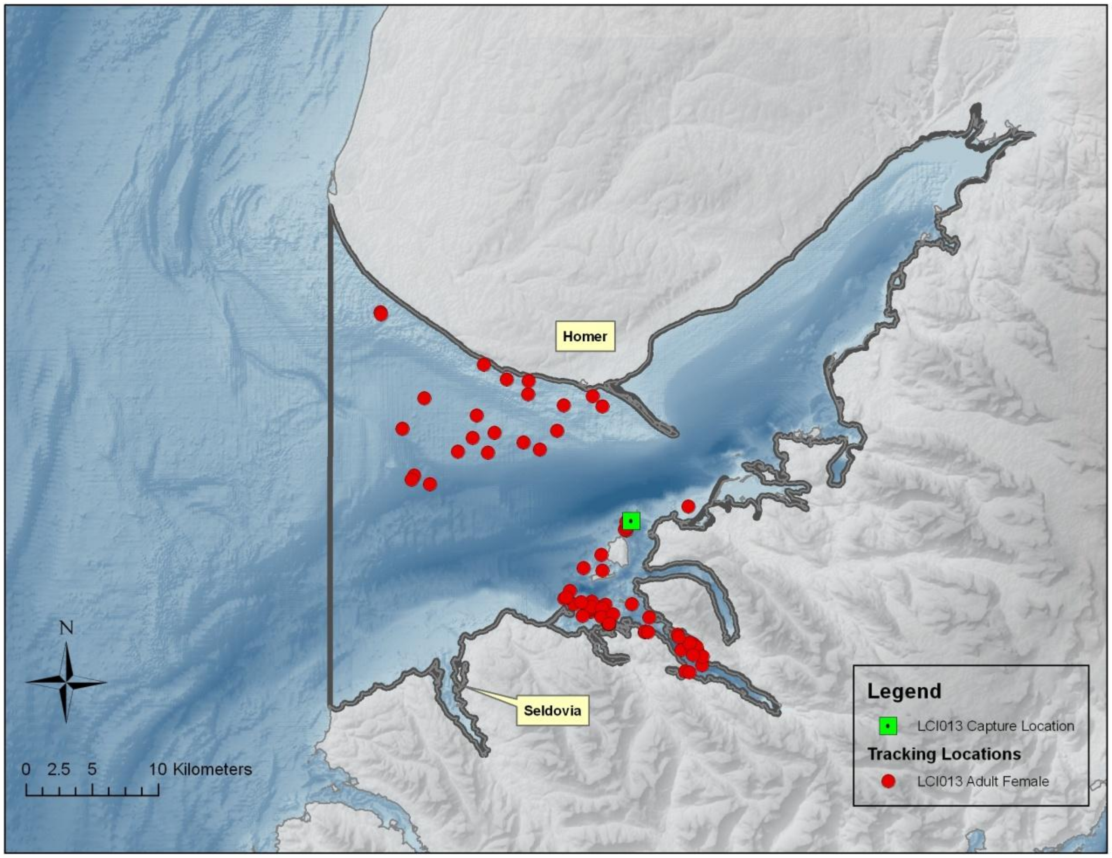
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI012 Capture Location
Tracking Locations
LCI012 Adult Male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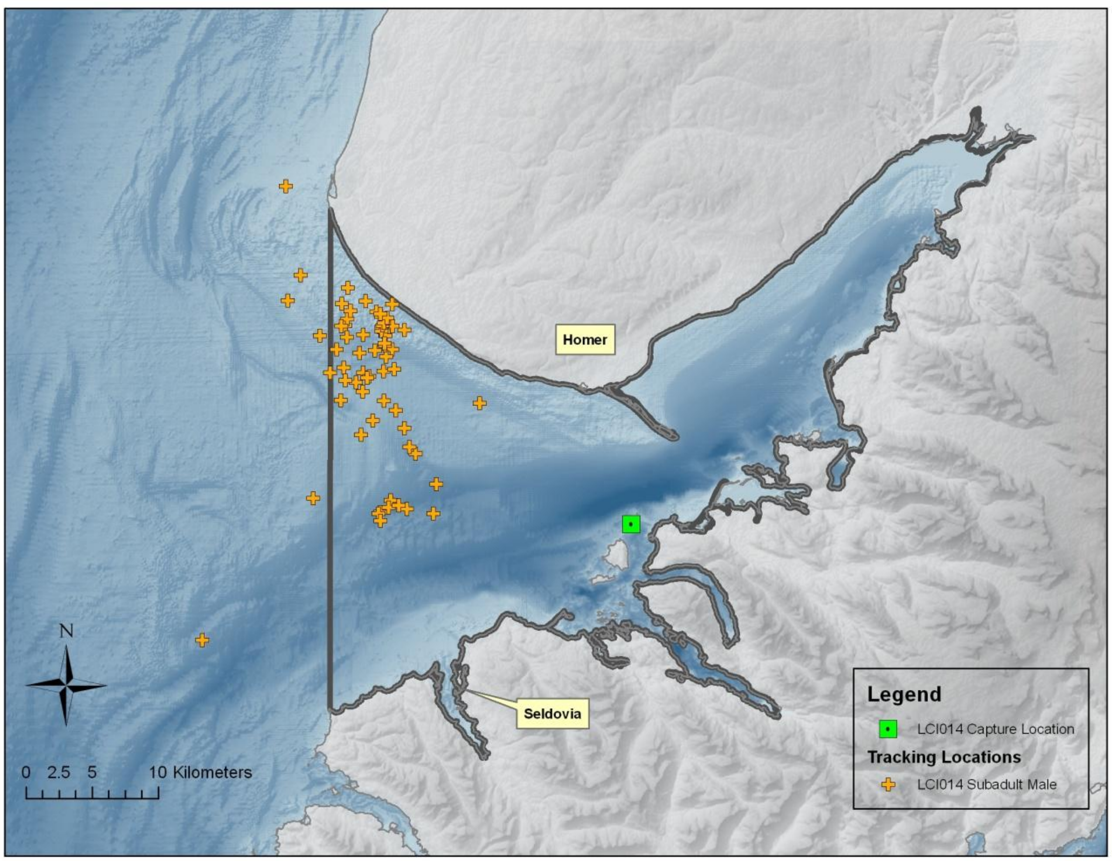
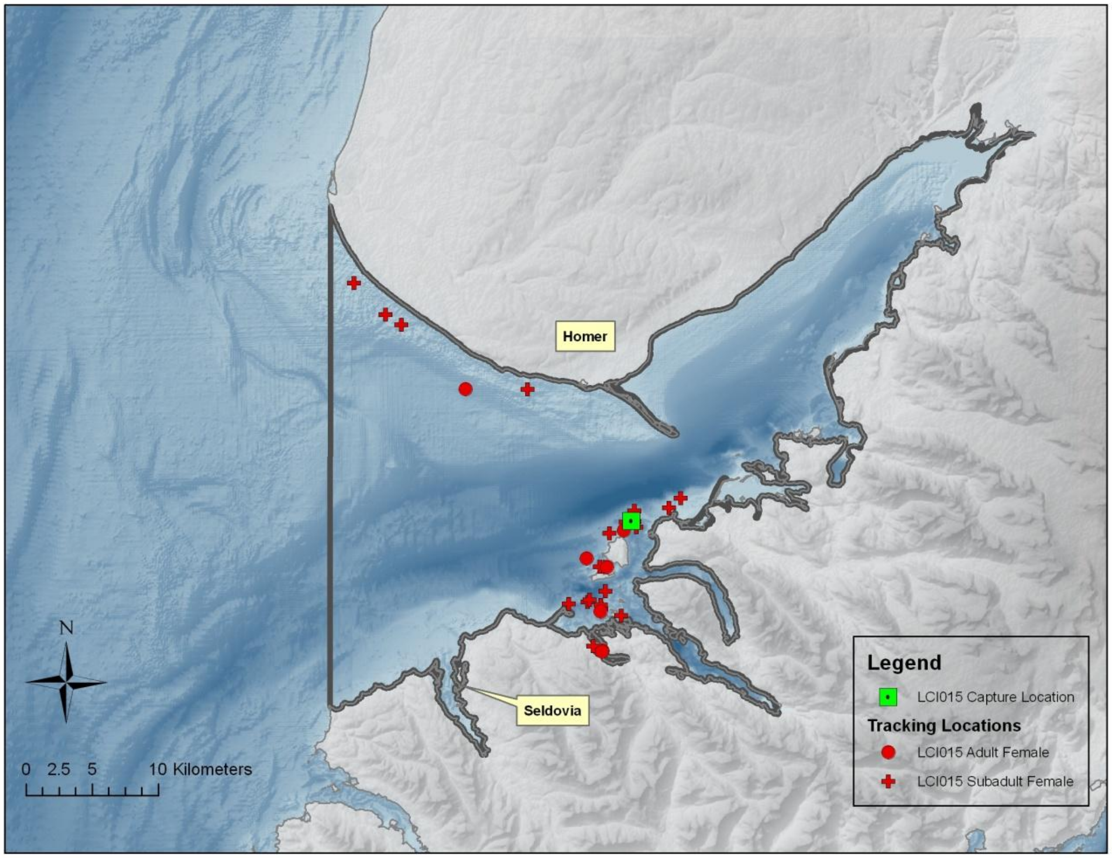
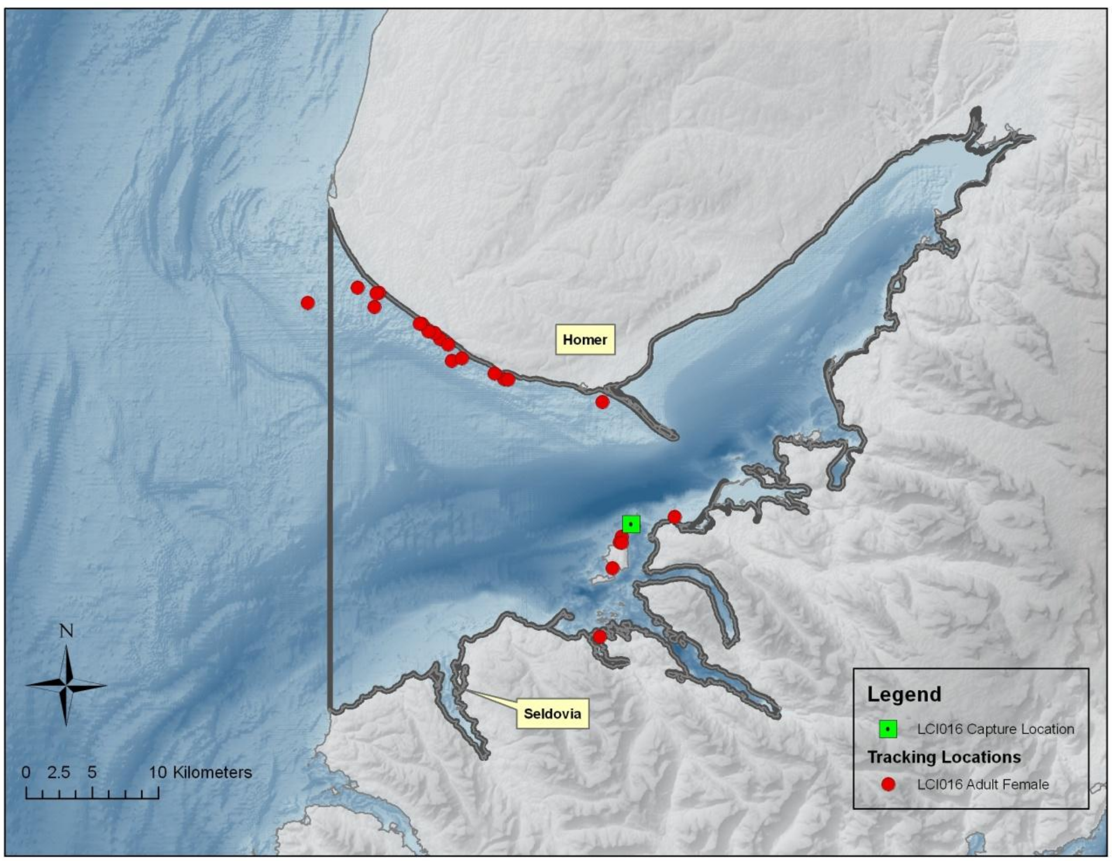
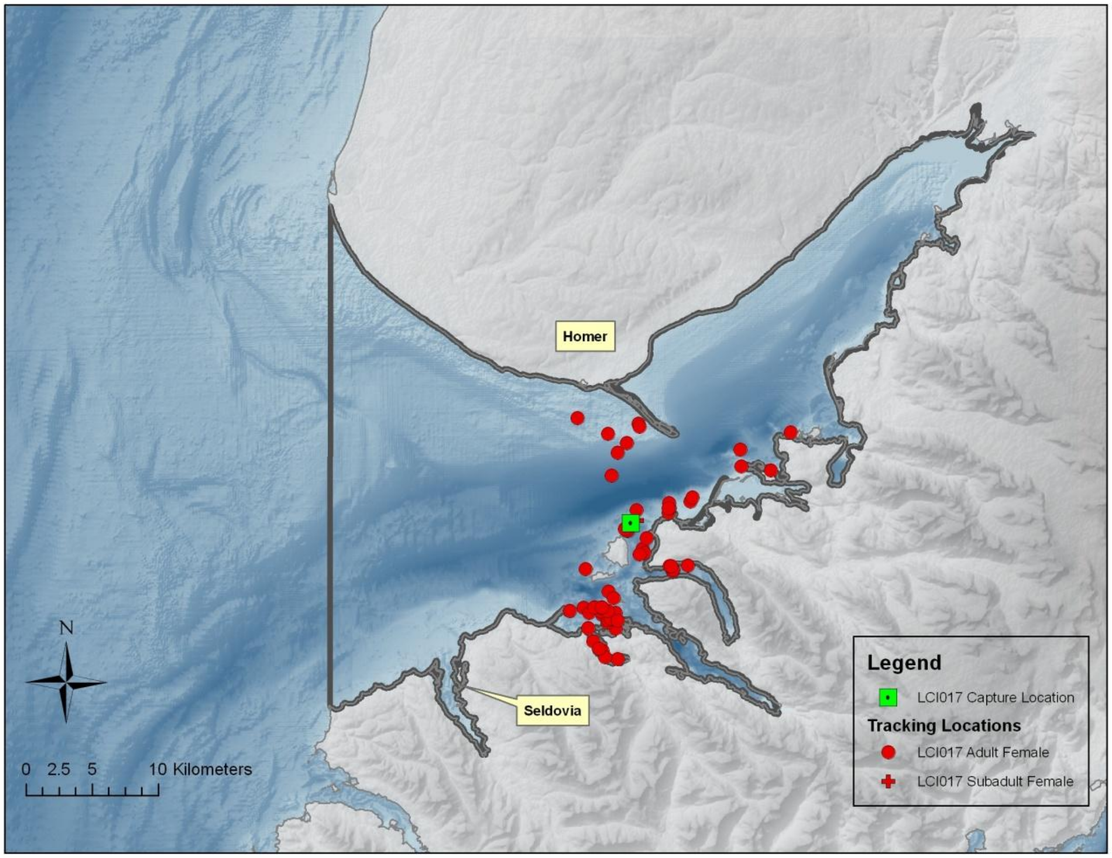
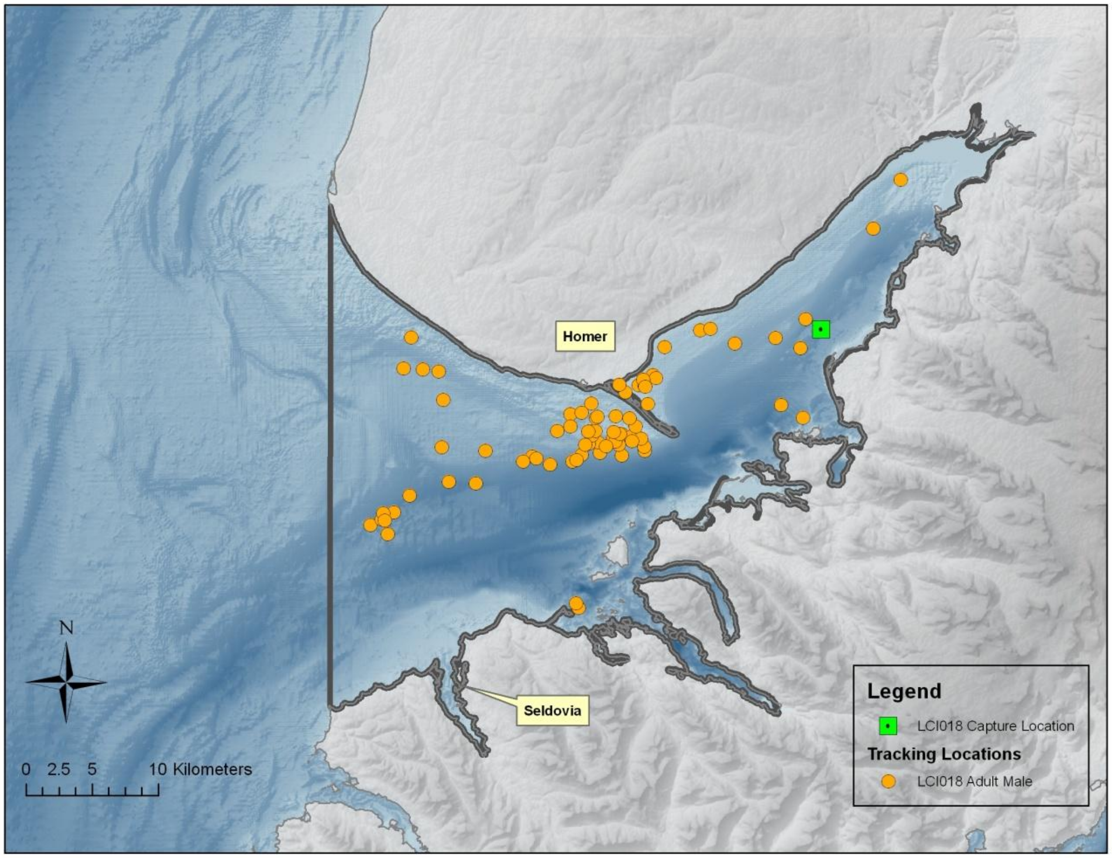
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI013 Capture Location
Tracking Locations
LCI013 Adult Female

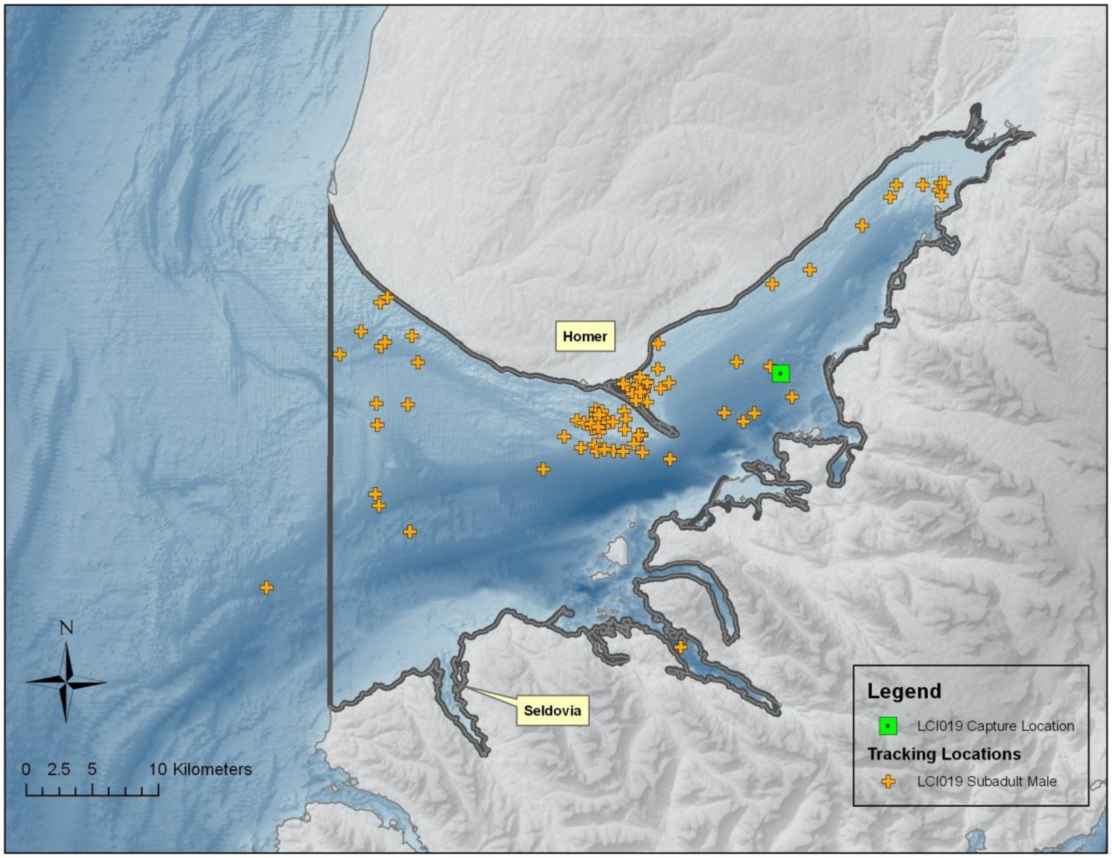

Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI014 Capture Location
Tracking Locations
LCI014 Subadult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI015 Capture Location
Tracking Locations
LCI015 Adult Female
LCI015 Subadult Female


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI016 Capture Location
Tracking Locations
LCI016 Adult Female


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI017 Capture Location
Tracking Locations
LCI017 Adult Female
LCI017 Subadult Female


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI018 Capture Location
Tracking Locations
LCI018 Adult Male


Homer
Seldovia
N
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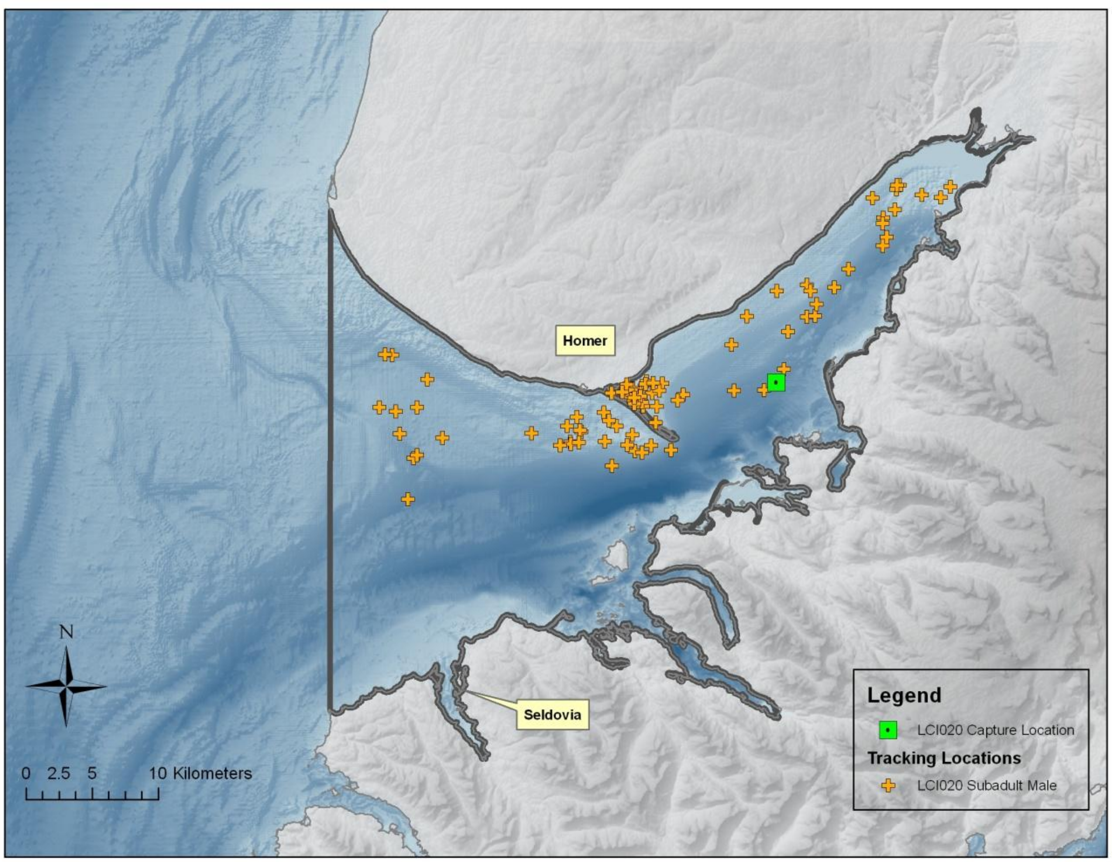
Legend
LCI019 Capture Location
Tracking Locations
LCI019 Subadult Male


Homer
Seldovia
N
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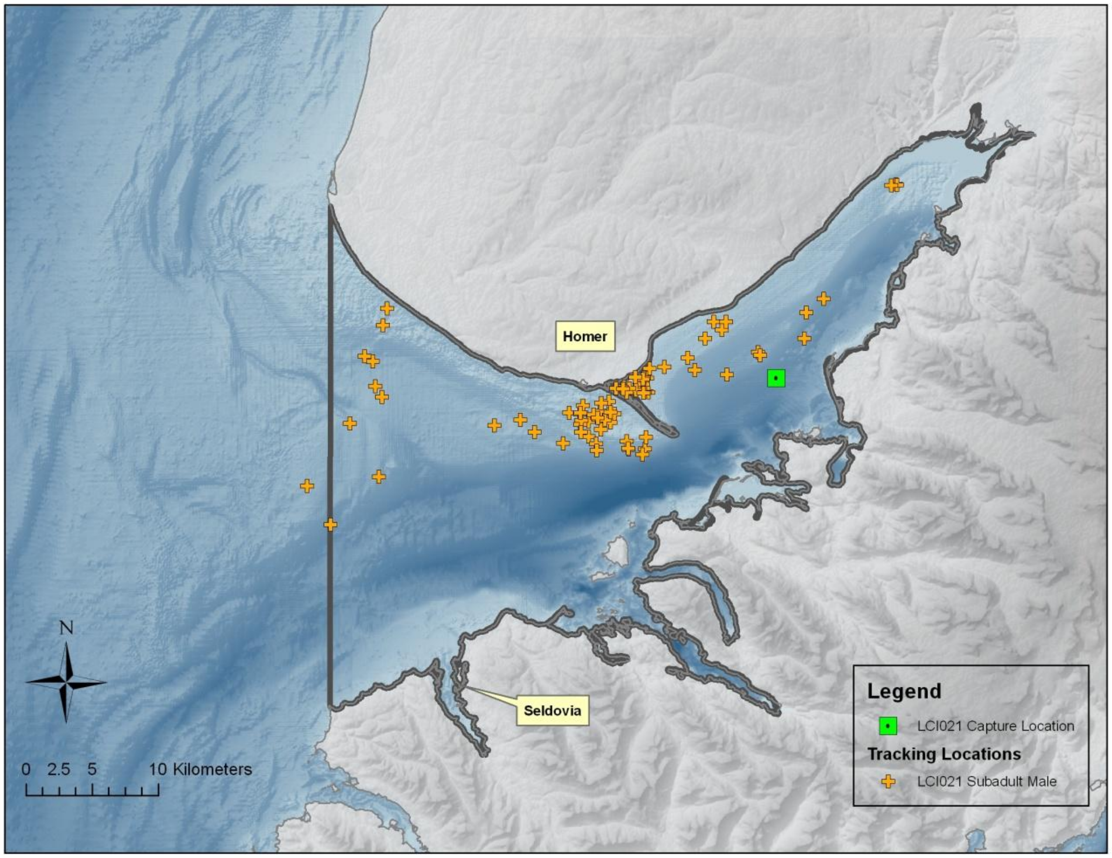
Legend
LCI020 Capture Location
Tracking Locations
LCI020 Subadult Male


Homer
Seldovia
N
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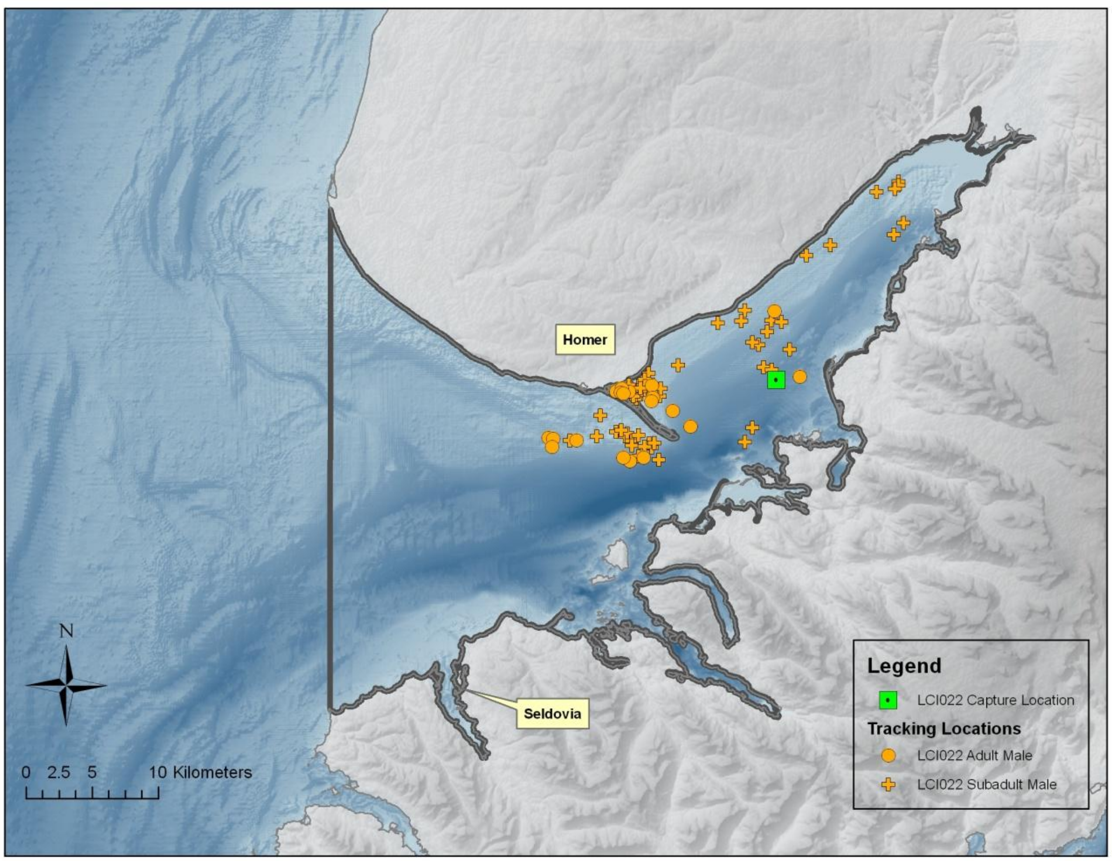
Legend
LCI021 Capture Location
Tracking Locations
LCI021 Subadult Male


Homer
Seldovia
N
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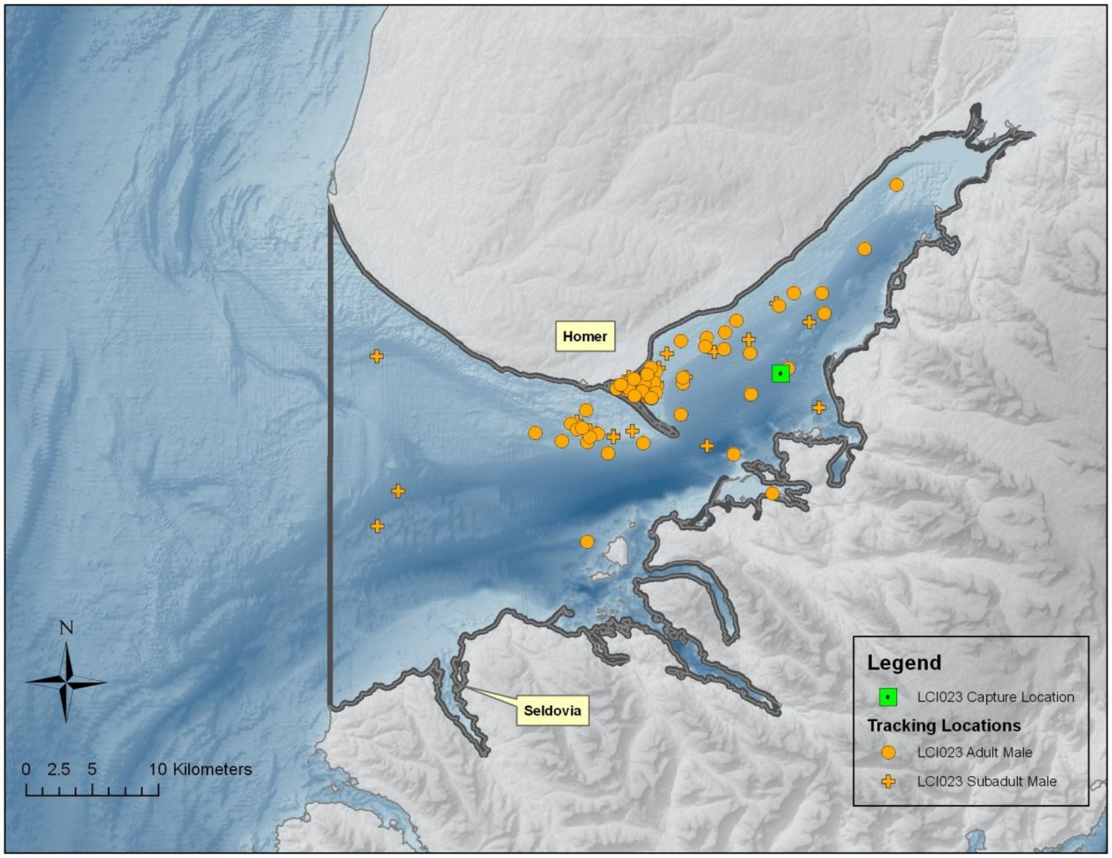
Legend
LCI022 Capture Location
Tracking Locations
LCI022 Adult Male
LCI022 Subadult Male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Seldovia
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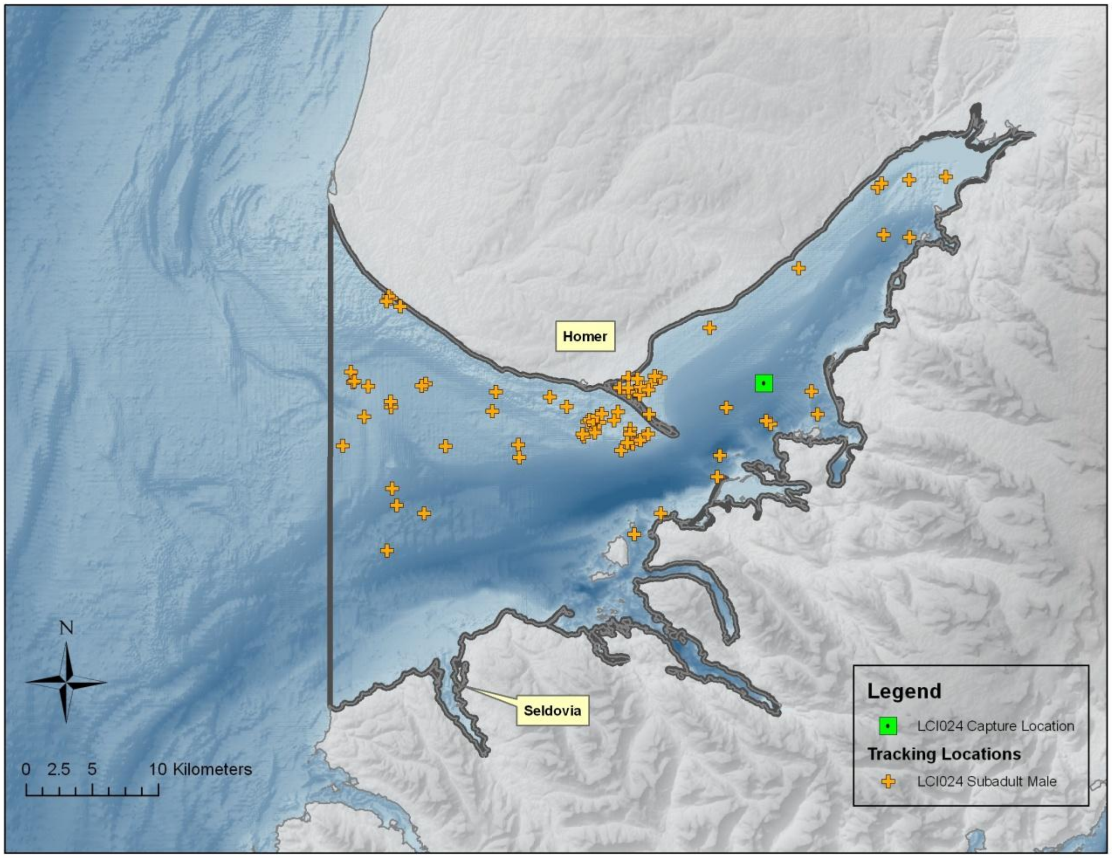
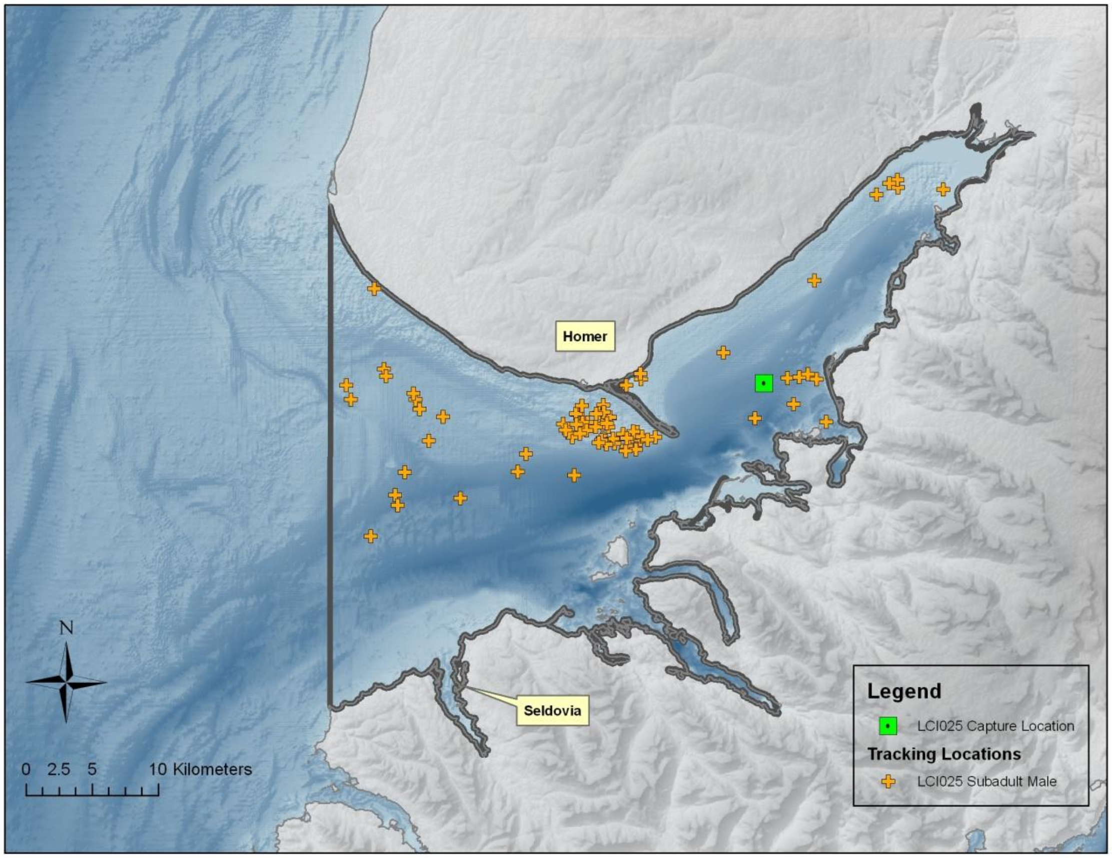
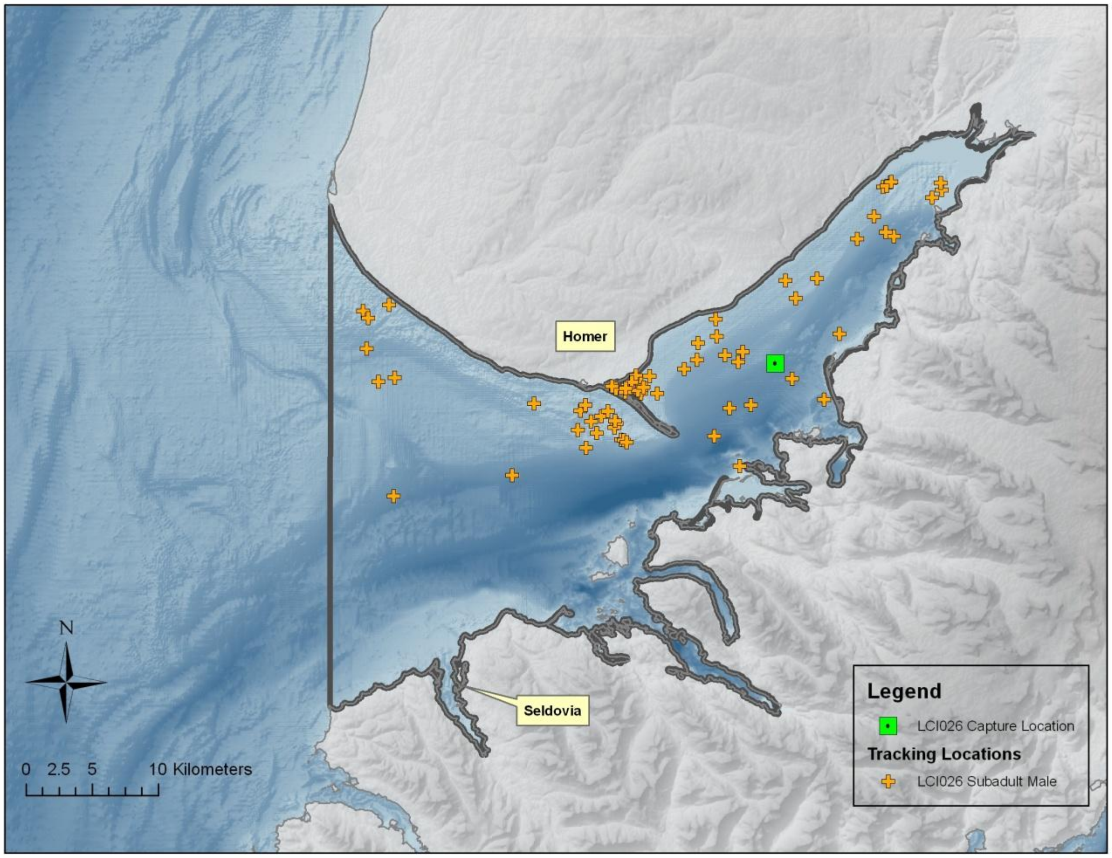
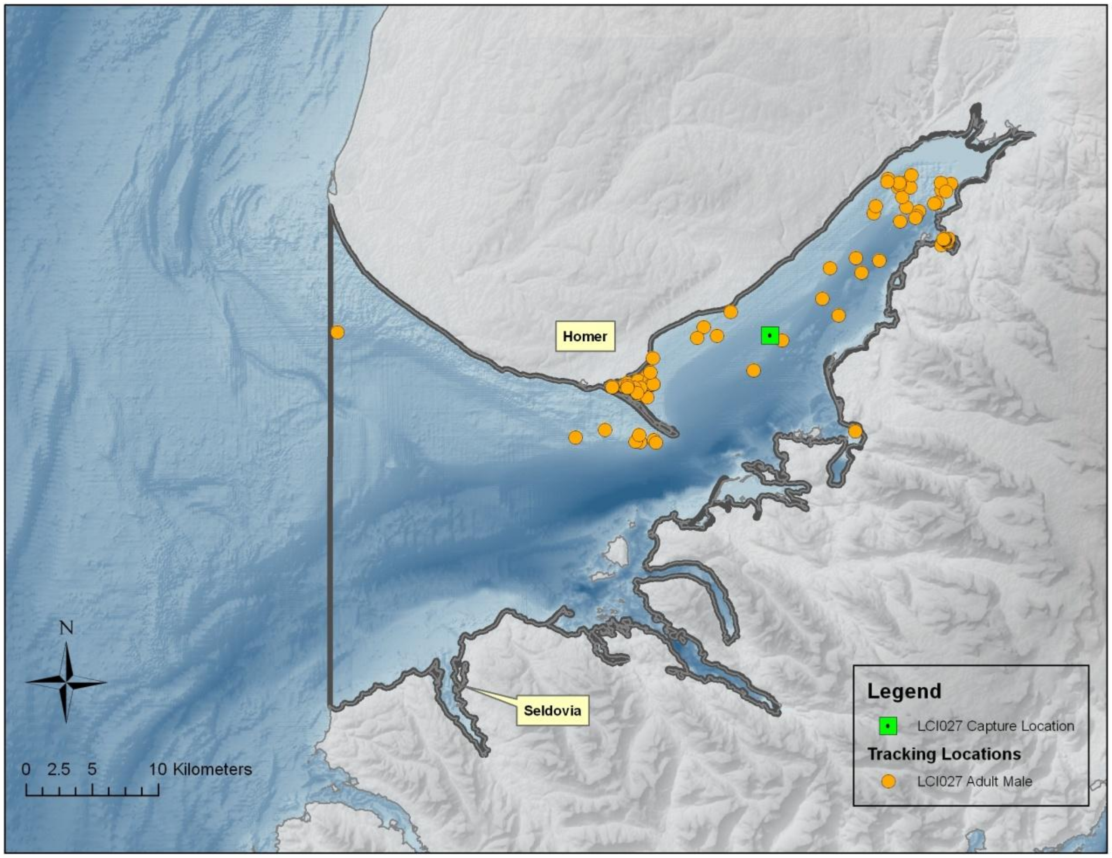
Legend
LCI023 Capture Location
Tracking Locations
LCI023 Adult Male
LCI023 Subadult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI024 Capture Location
Tracking Locations
LCI024 Subadult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI025 Capture Location
Tracking Locations
LCI025 Subadult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI026 Capture Location
Tracking Locations
LCI026 Subadult Male



Homer
Seldovia
N
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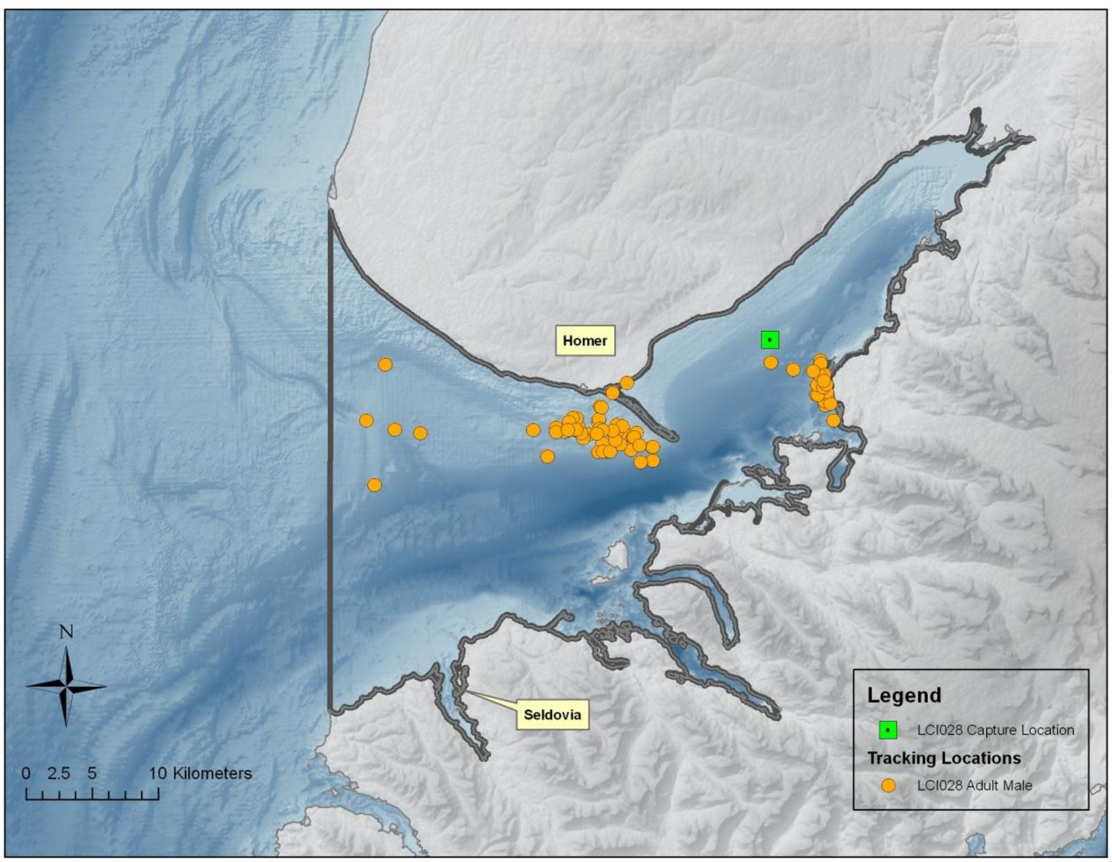
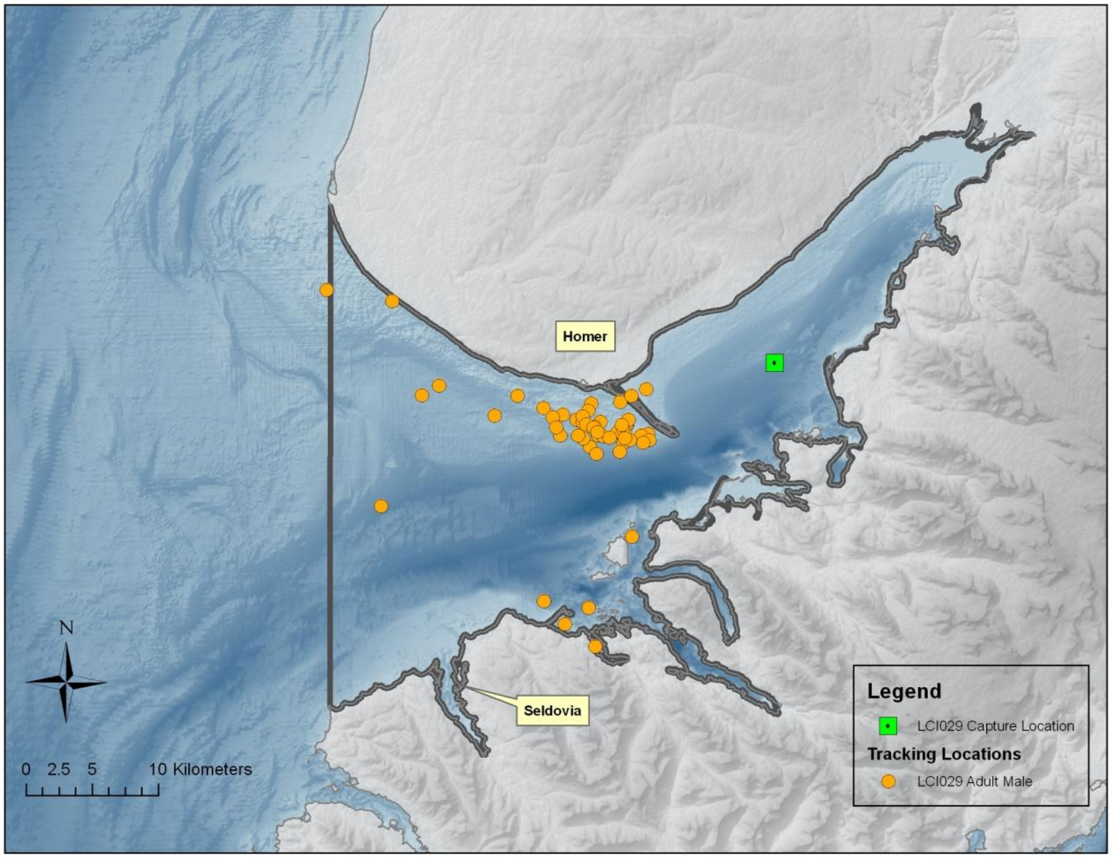
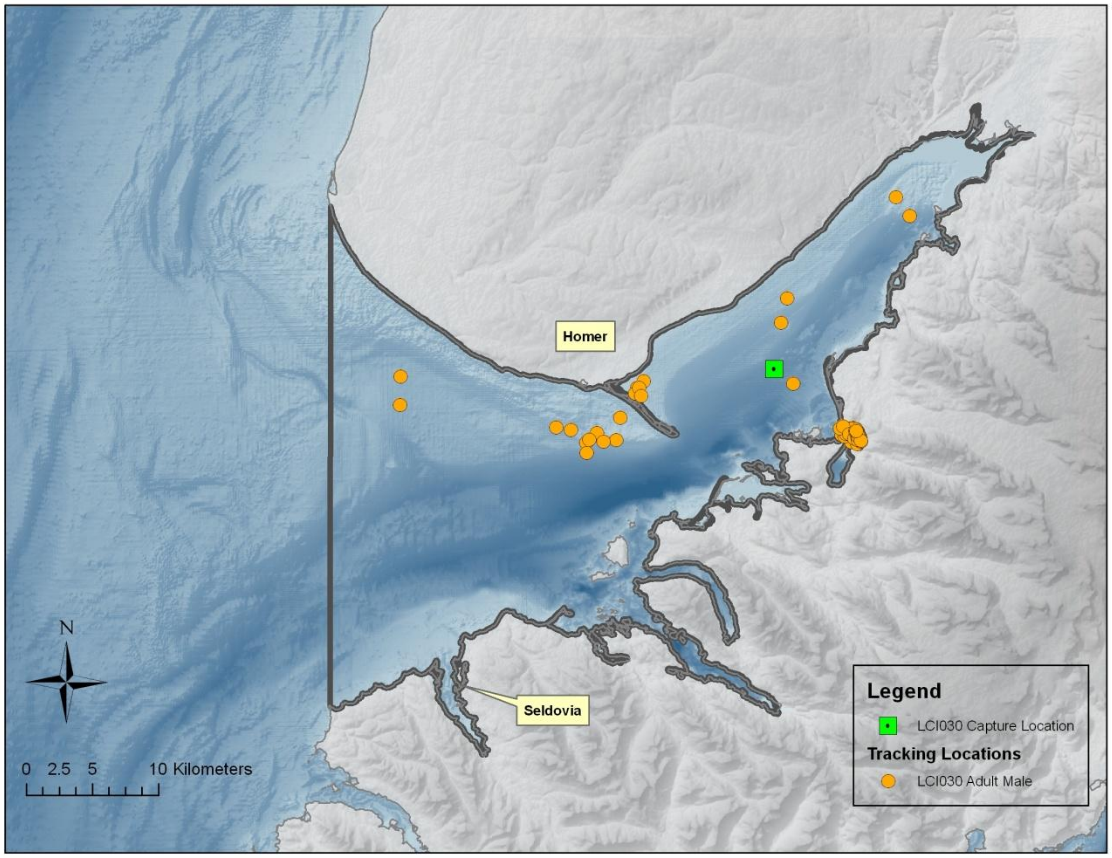
Legend
LCI027 Capture Location
Tracking Locations
LCI027 Adult Male



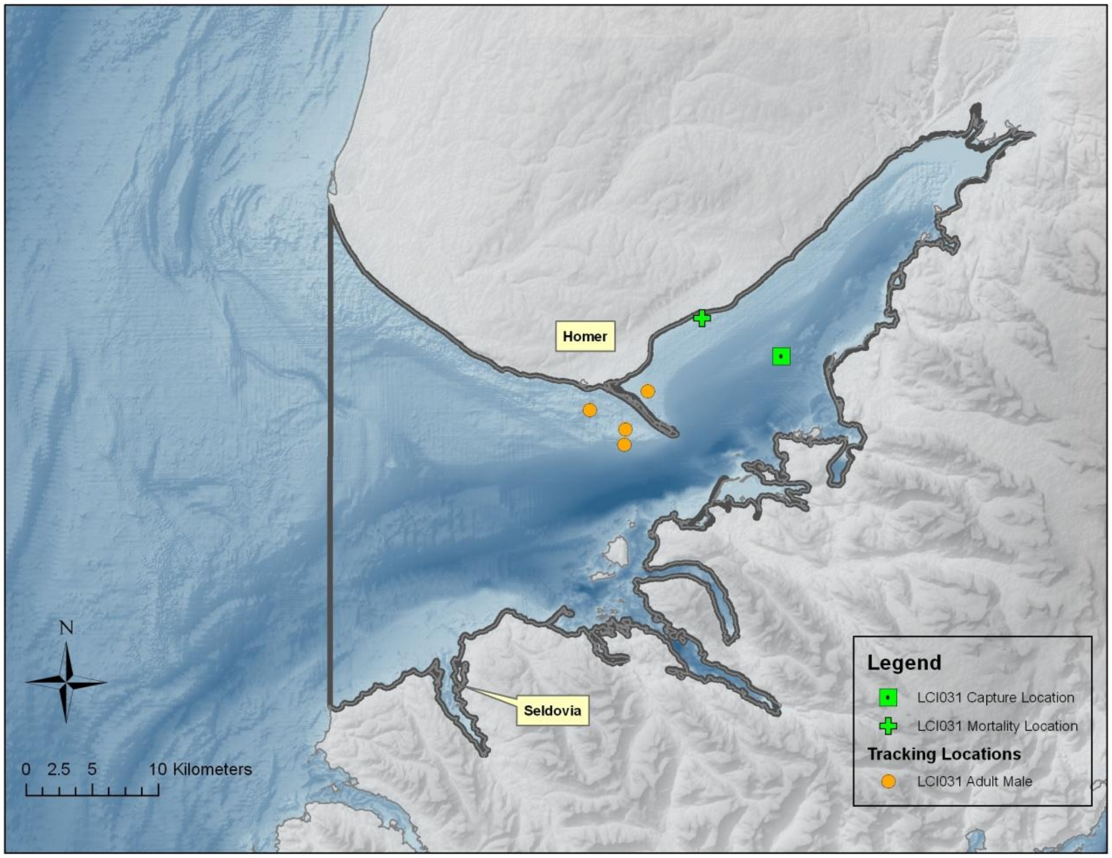
Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI028 Capture Location
Tracking Locations
LCI028 Adult Male

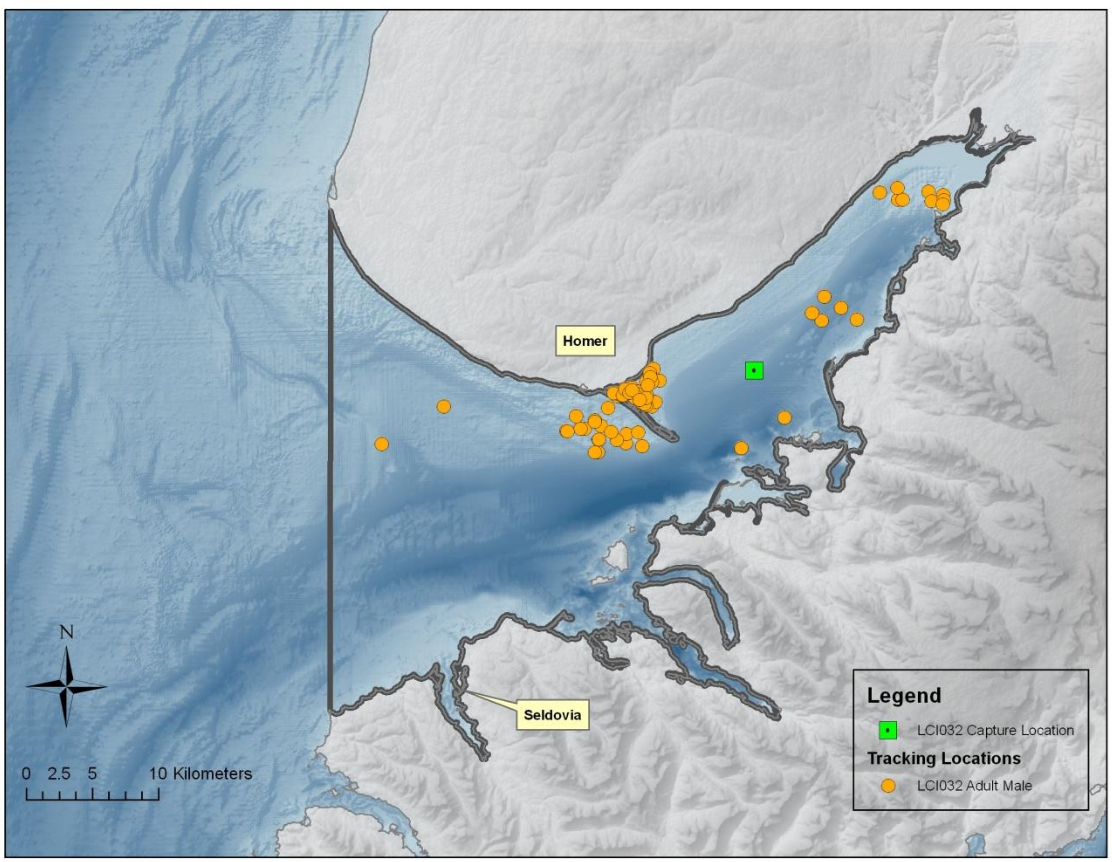


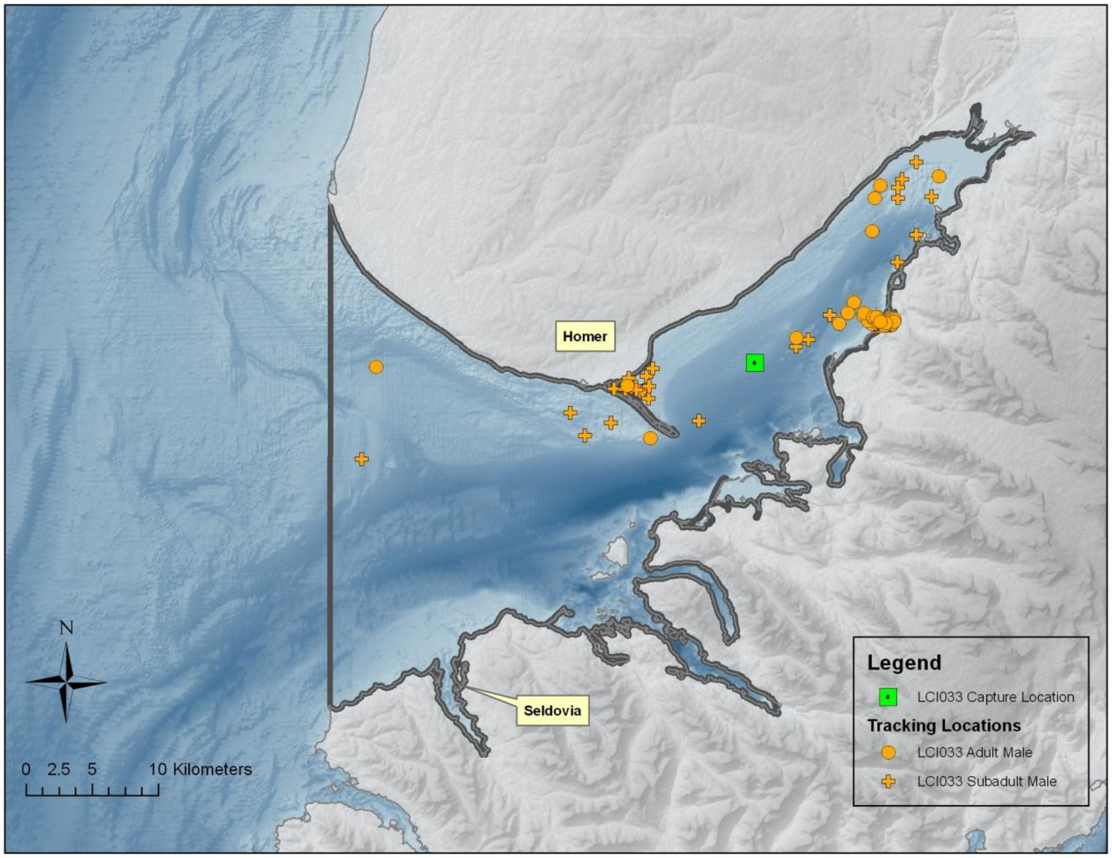
Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI029 Capture Location
Tracking Locations
LCI029 Adult Male

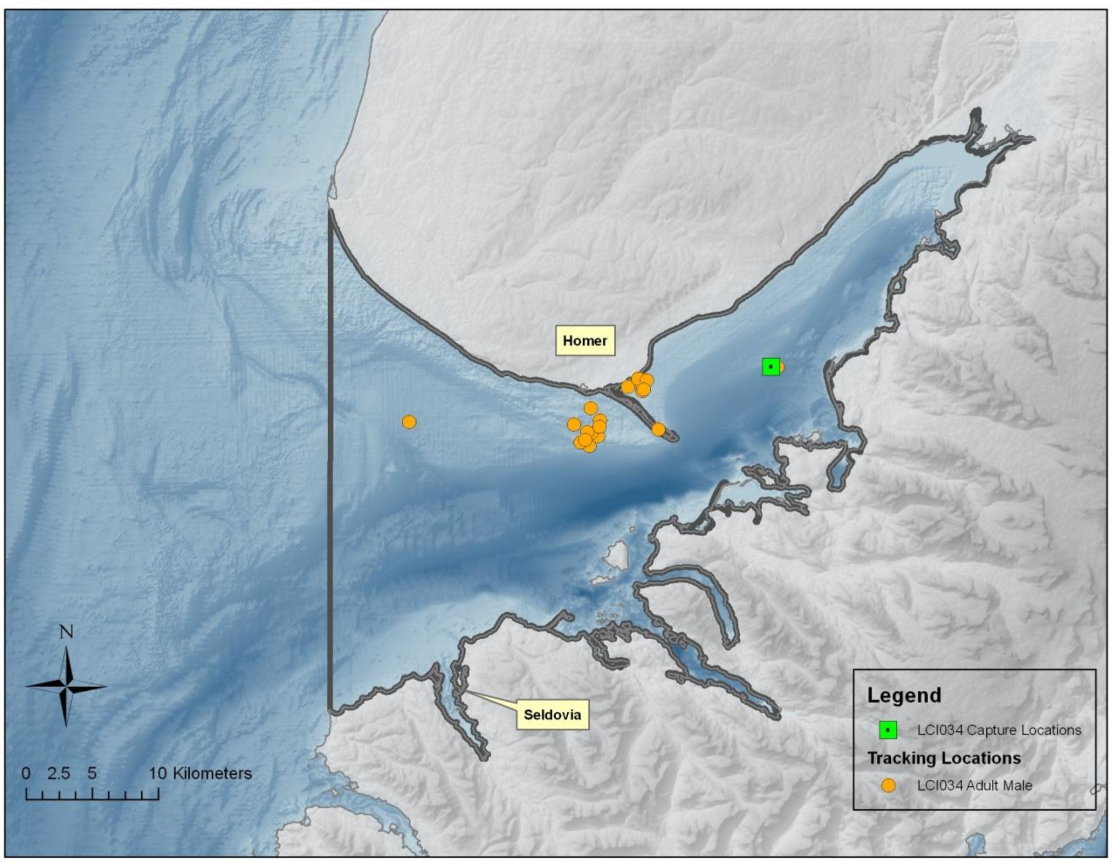


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI030 Capture Location
Tracking Locations
LCI030 Adult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI031 Capture Location
LCI031 Mortality Location
Tracking Locations
LCI031 Adult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI032 Capture Location
Tracking Locations
LCI032 Adult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI033 Capture Location
Tracking Locations
LCI033 Adult Male
LCI033 Subadult Male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Seldovia
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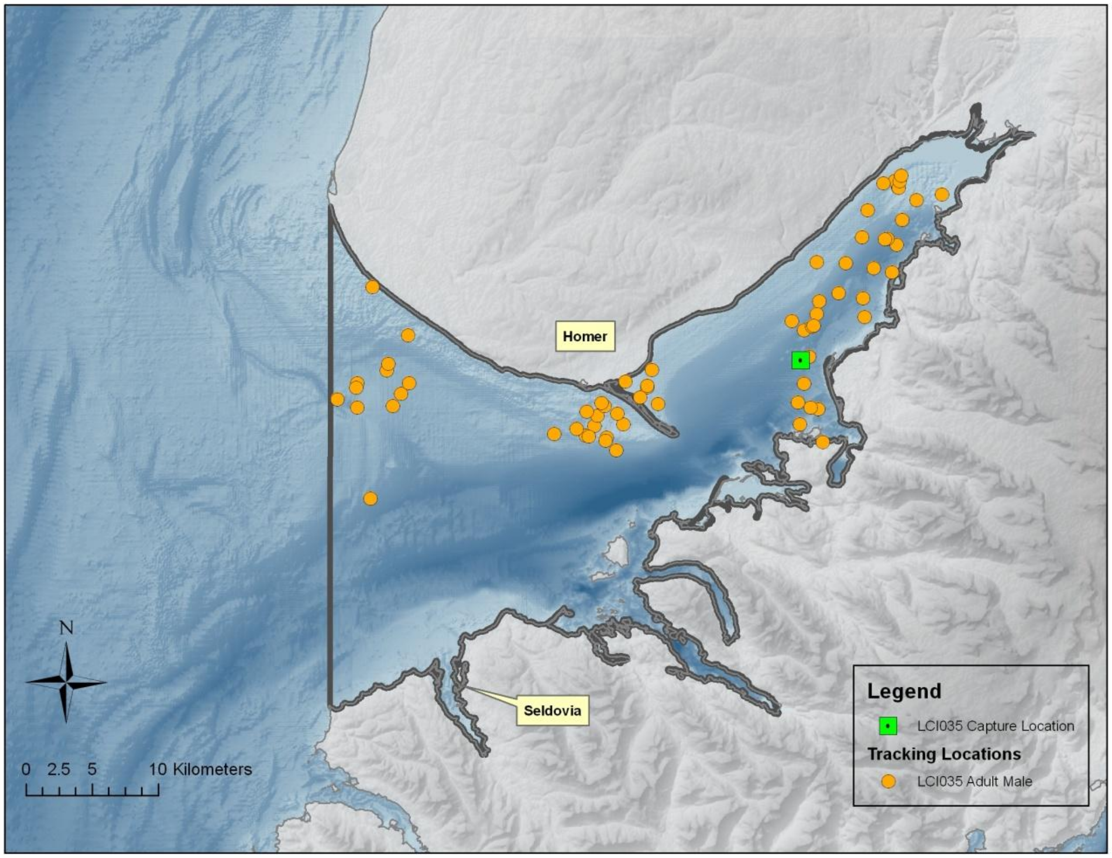
Legend
LCI034 Capture Locations
Tracking Locations
LCI034 Adult Male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Seldovia
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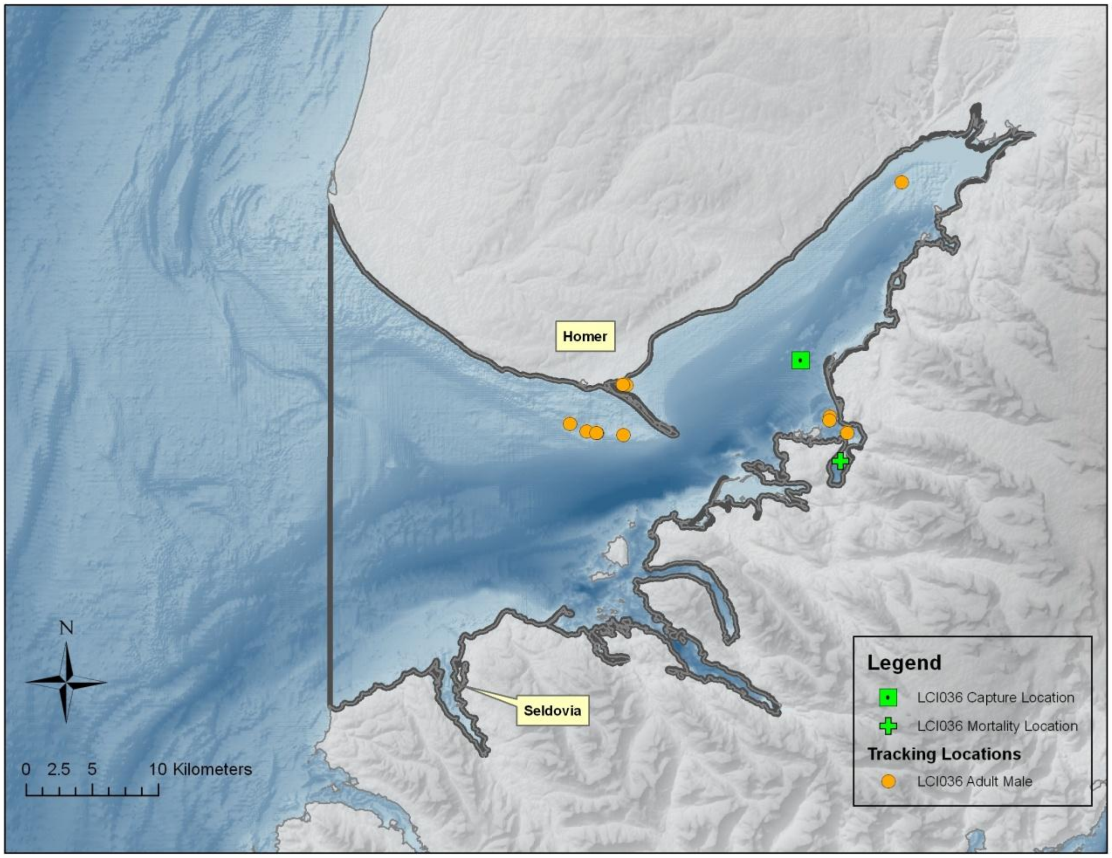
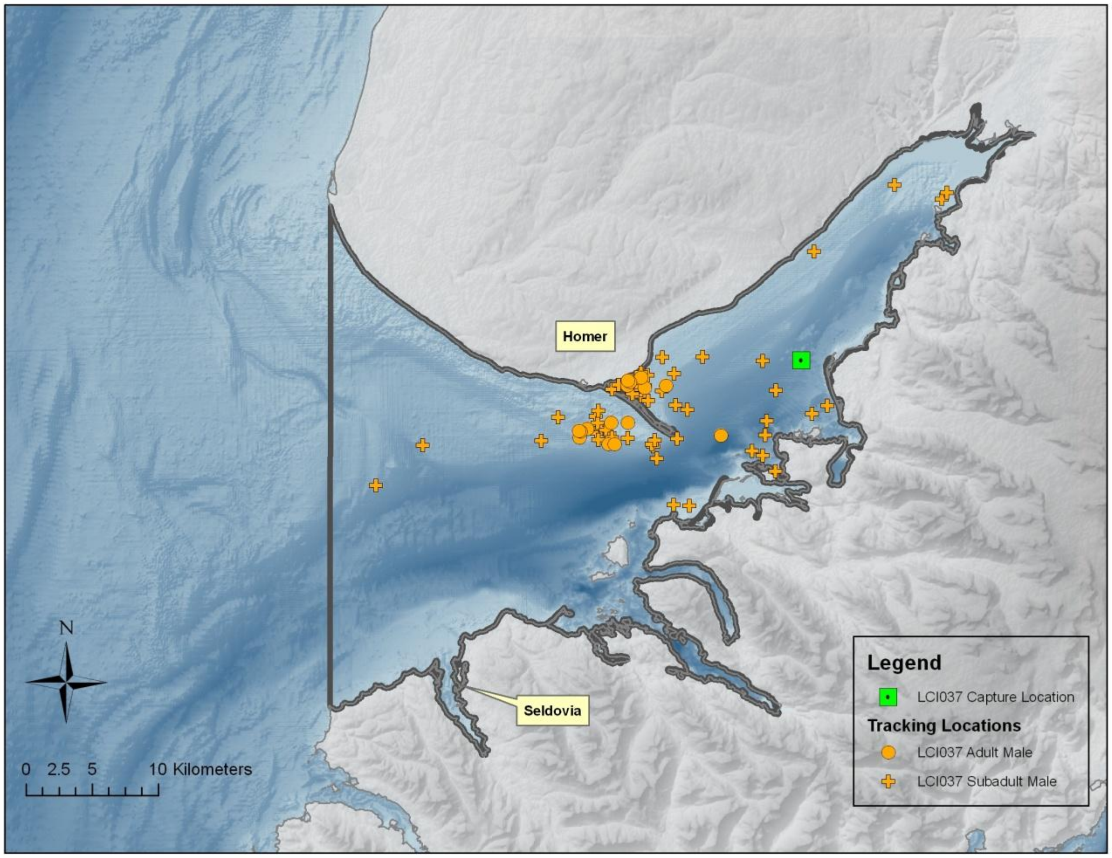
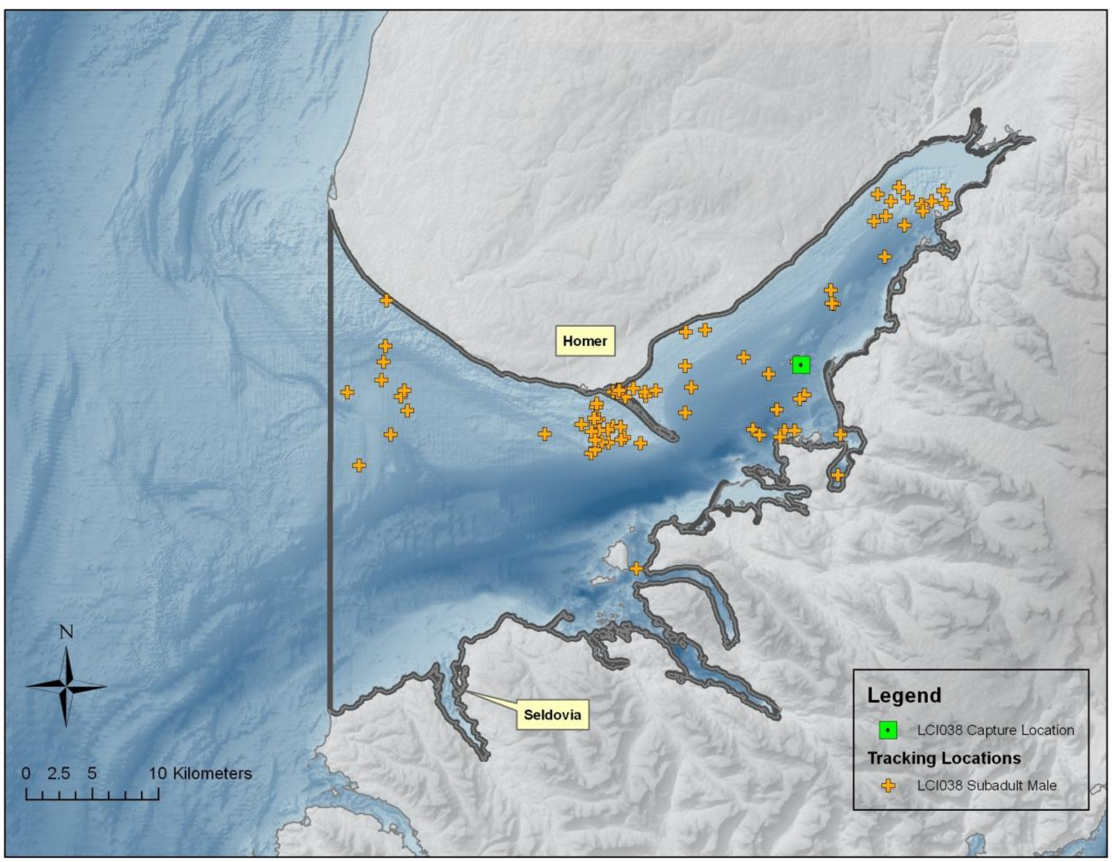
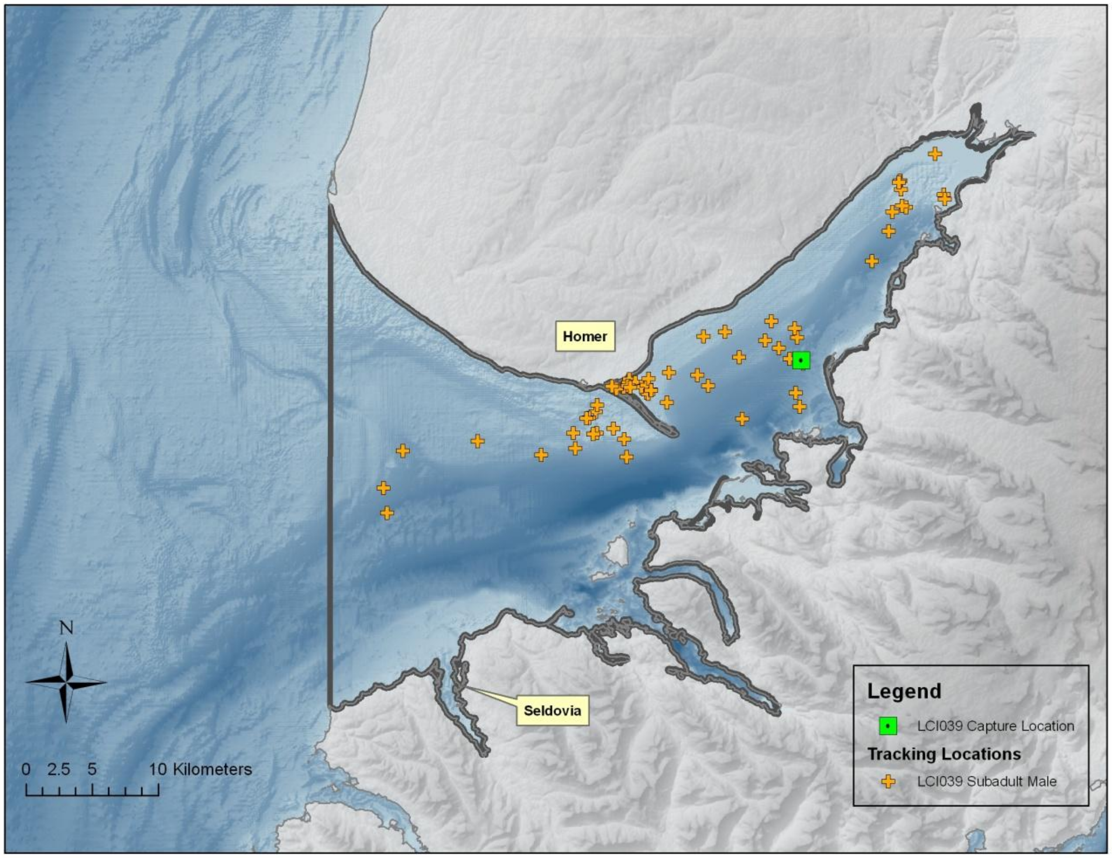
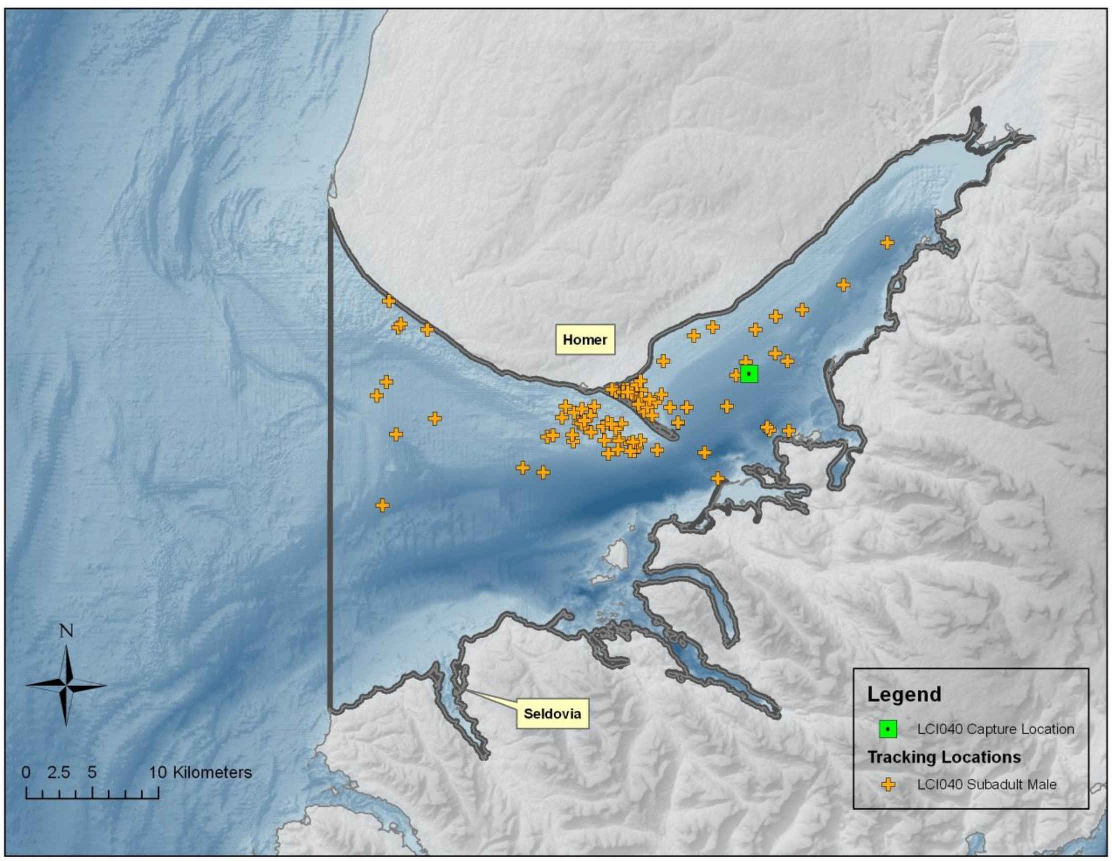
Legend
LCI035 Capture Location
Tracking Locations
LCI035 Adult Male

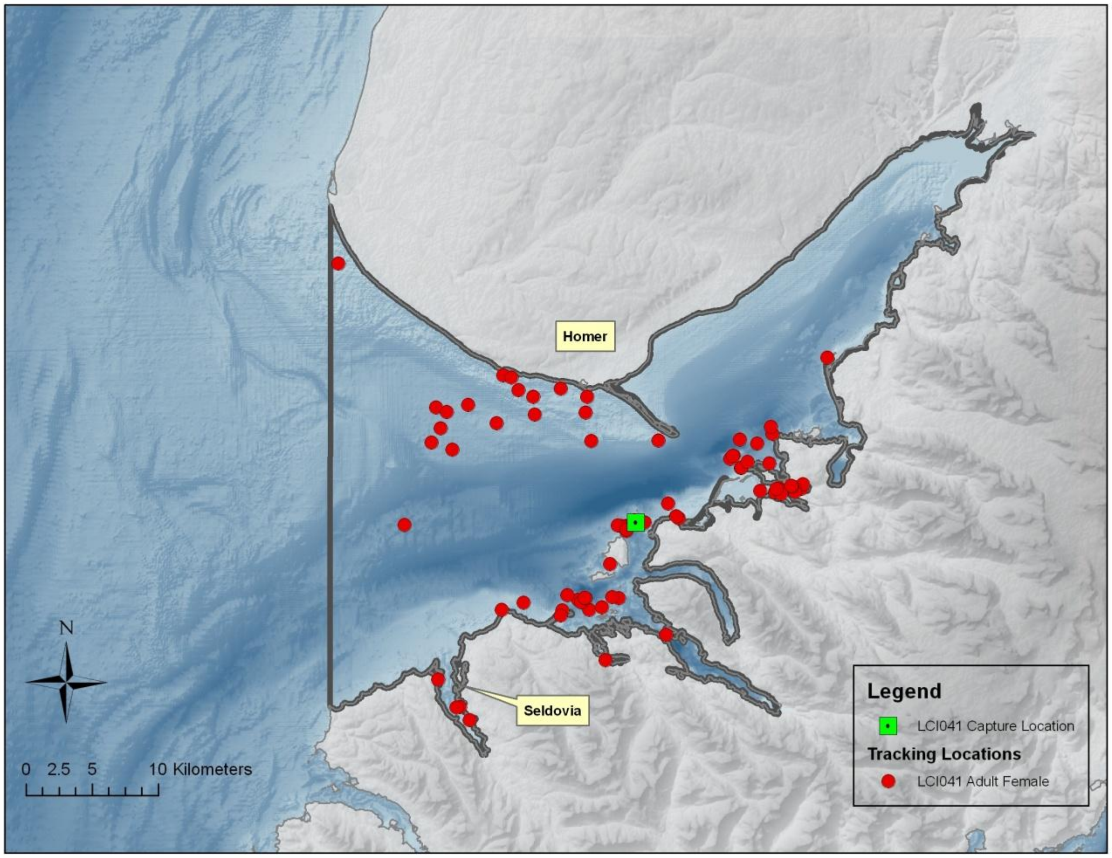

Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI036 Capture Location
LCI036 Mortality Location
Tracking Locations
LCI036 Adult Male

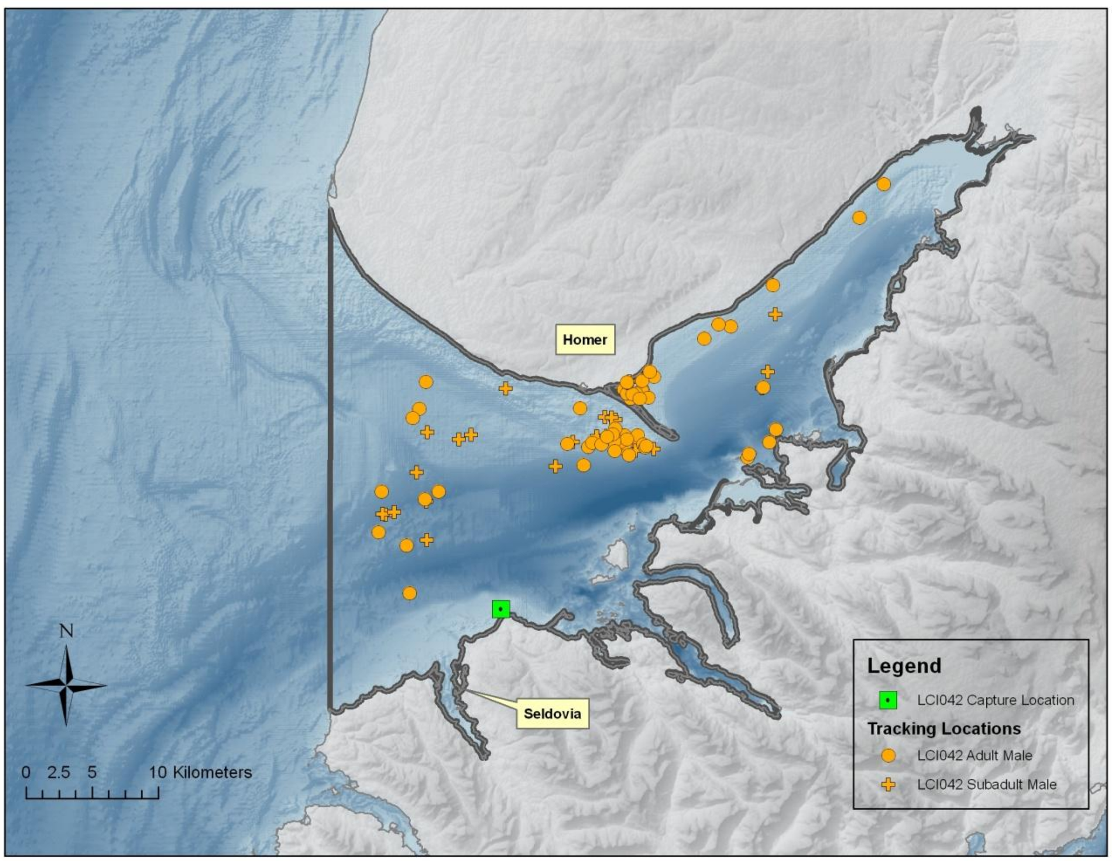

Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI037 Capture Location
Tracking Locations
LCI037 Adult Male
LCI037 Subadult Male

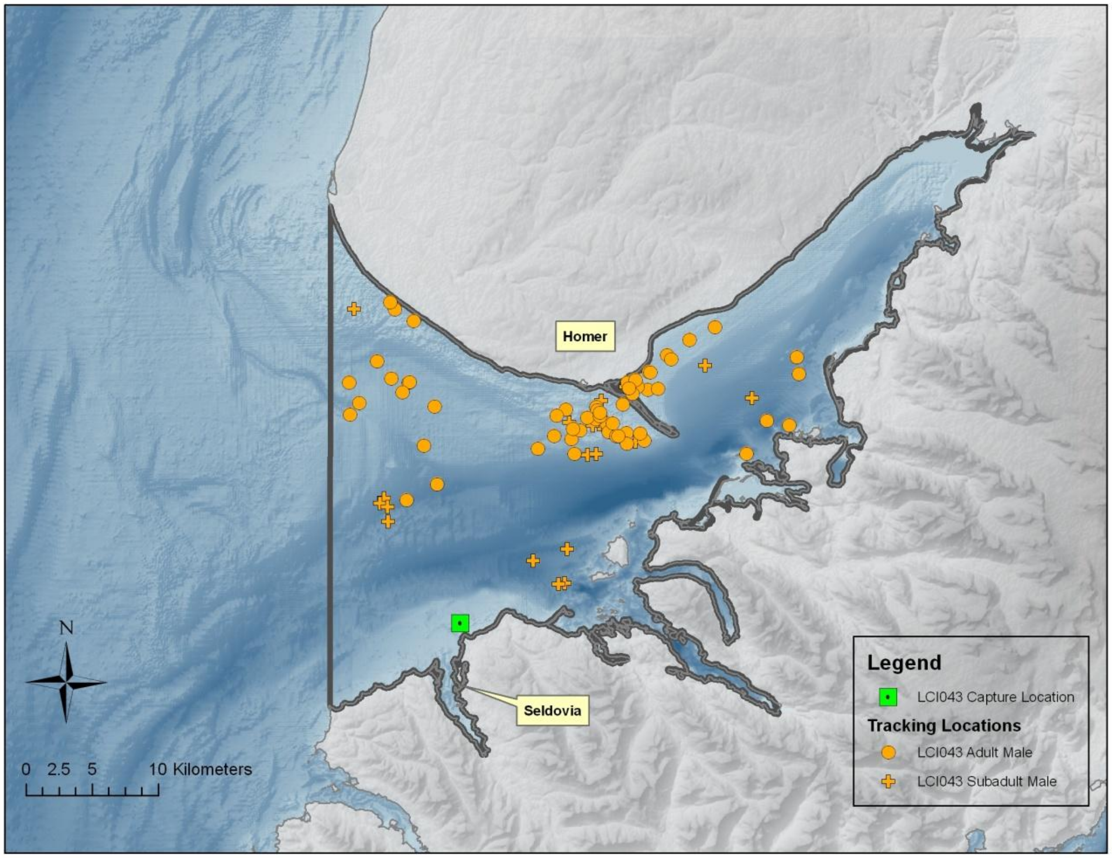

Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI038 Capture Location
Tracking Locations
LCI038 Subadult Male

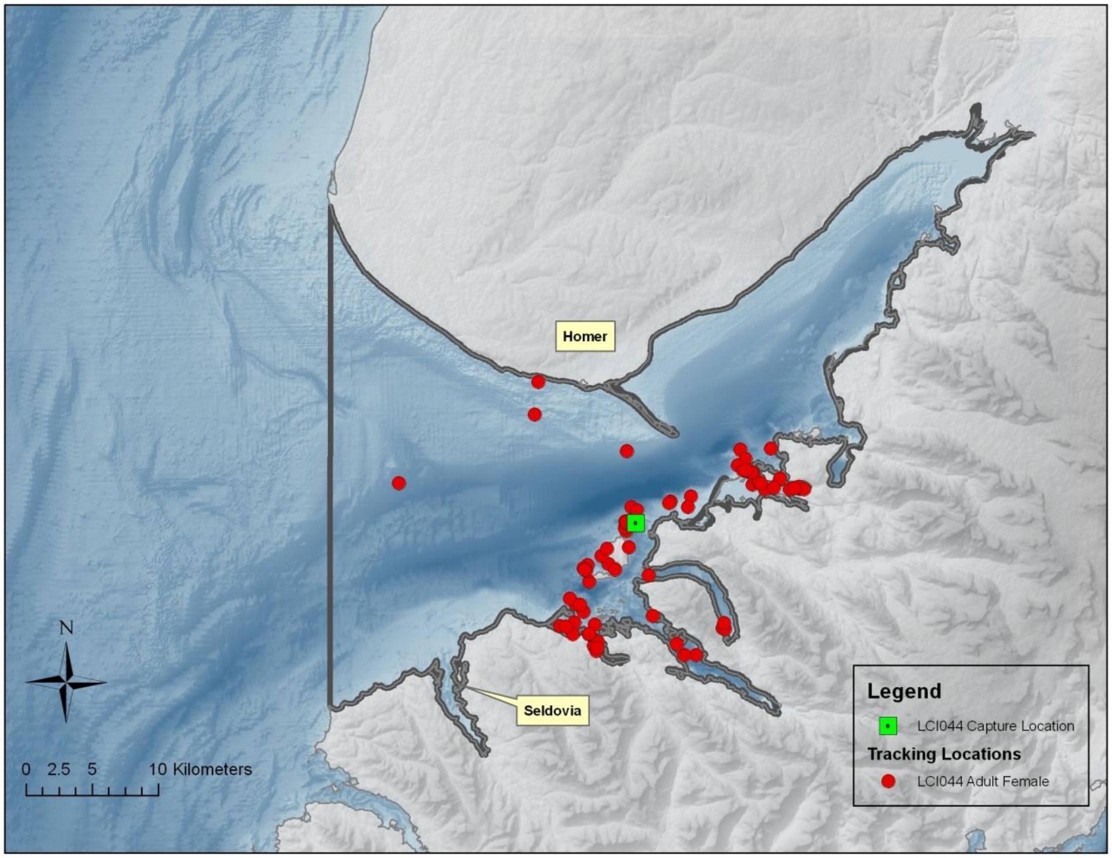

Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI039 Capture Location
Tracking Locations
LCI039 Subadult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI040 Capture Location
Tracking Locations
LCI040 Subadult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI041 Capture Location
Tracking Locations
LCI041 Adult Female


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI042 Capture Location
Tracking Locations
LCI042 Adult Male
LCI042 Subadult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI043 Capture Location
Tracking Locations
LCI043 Adult Male
LCI043 Subadult Male


Homer
Seldovia
N
0 2.5 5 10 Kilometers
Legend
LCI044 Capture Location
Tracking Locations
LCI044 Adult Female